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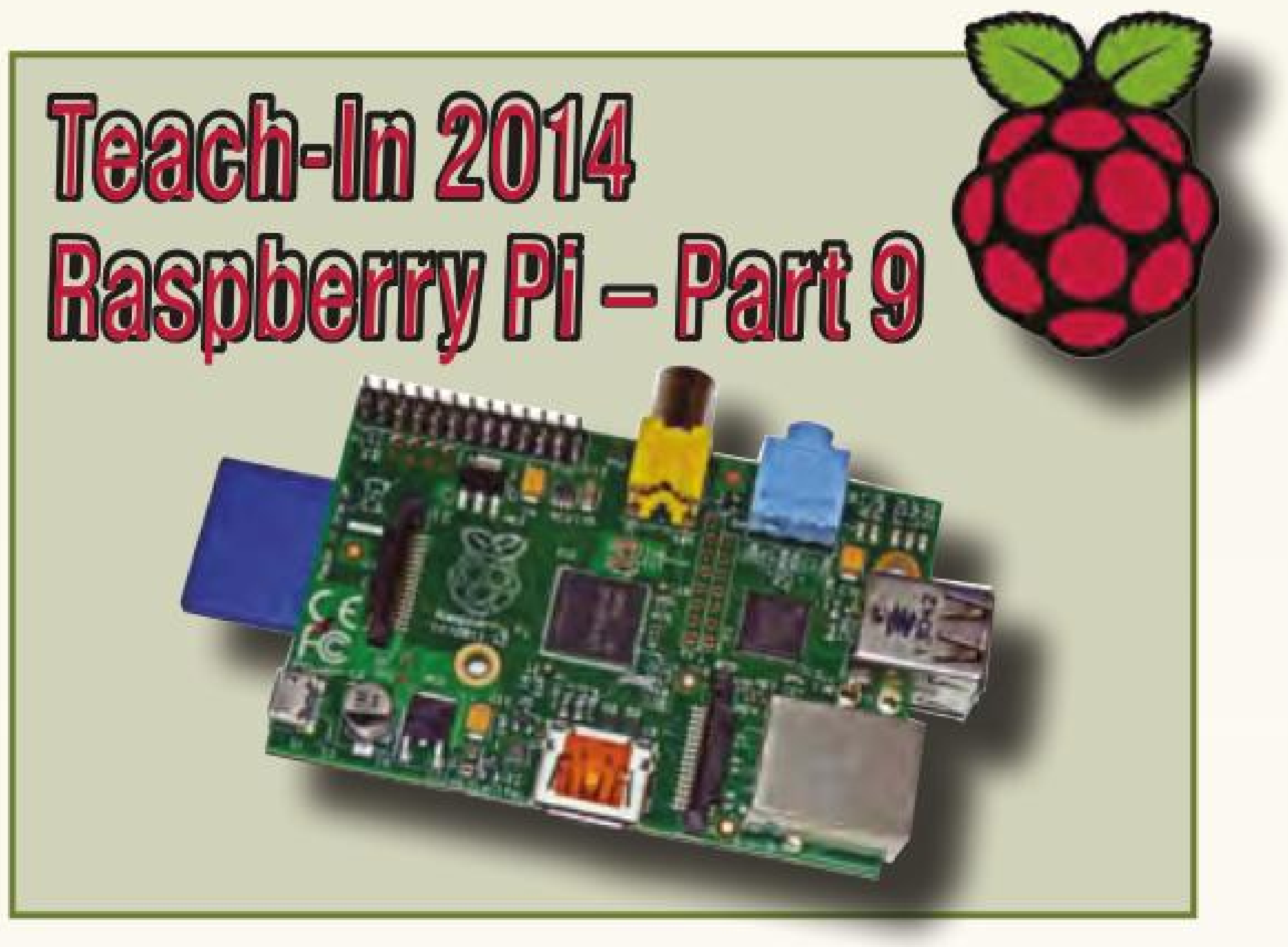

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Assembled with ZIF socket Order Code: AS3149EZIF - £74.95

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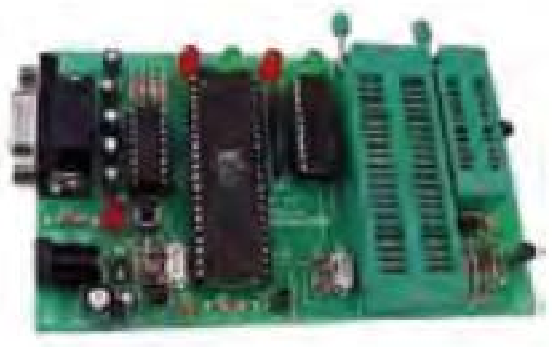

Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. 16Vdc.
*Kit Order Code: 3123KT - **£28.95***
*Assembled Order Code: AS3123 - **£39.95***

Introduction to PIC Programming

Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual + Programming Hardware (with LED test section) + Windows Software (Program, Read, Verify & Erase) + a rewritable PIC16F84A. 4 detailed examples provided for you to learn from. PC parallel port. 12Vdc.
*Kit Order Code: 3081KT - **£16.95***
*Assembled Order Code: AS3081 - **£24.95***

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Low cost PIC programmer board supporting a wide range of Microchip® PIC™ microcontrollers. Serial port. Free Windows software.
*Kit Order Code: K8076 - **£29.94***

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PIC Programmer & Experimenter Board with test buttons and LED indicators to carry out educational experiments such as the supplied programming examples. Includes a 16F627 Flash Microcontroller that can be reprogrammed up to 1000 times. Software to compile and program your source code is included. Supply: 12-15Vdc.
*Kit Order Code: K8048 - **£23.94***
*Assembled Order Code: VM111 - **£39.12***

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code 660.446UK £10.95

USB Experiment Interface Board

5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.
*Kit Order Code: K8055N - **£25.19***
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*Kit Order Code: 8157KT - **£49.95***
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Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
*Kit Order Code: 3145KT - **£19.95***
*Assembled Order Code: AS3145 - **£26.95***
*Additional DS1820 Sensors - **£4.95 each***

Remote Control Via GSM Mobile Phone

Place next to a mobile phone (not included). Allows toggle or auto-timer control of 3A mains rated output relay from any location with GSM coverage.
*Kit Order Code: MK160 - **£10.72***

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

4-Ch DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, **Rings** to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.
*Kit Order Code: 3140KT - **£79.95***
*Assembled Order Code: AS3140 - **£94.95***

8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.
*Kit Order Code: 3108KT - **£74.95***
*Assembled Order Code: AS3108 - **£89.95***

Infrared RC 12–Channel Relay Board

Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12Vdc/0.5A
*Kit Order Code: 3142KT - **£64.95***
*Assembled Order Code: AS3142 - **£74.95***

Audio DTMF Decoder and Display

Detect DTMF tones from tape recorders, receivers, two-way radios, etc using the built-in mic *or* direct from the phone line. Characters are displayed on a 16 character display as they are received and up to 32 numbers can be displayed by scrolling the display. All data written to the LCD is also sent to a serial output for connection to a computer. Supply: 9-12V DC (Order Code PSU375). Main PCB: 55x95mm.
*Kit Order Code: 3153KT - **£37.95***
*Assembled Order Code: AS3153 - **£49.95***

3x5Amp RGB LED Controller with RS232

3 independent high power channels. Preprogrammed or user-editable light sequences. Standalone option and 2-wire serial interface for microcontroller or PC communication with simple command set. Suitable for common anode RGB LED strips, LEDs and incandescent bulbs. 56 x 39 x 20mm. 12A total max. Supply: 12Vdc.
Kit Order Code: 8191KT - £29.95
Assembled Order Code: AS8191 - £39.95

Hot New Products!

Here are a few of the most recent products added to our range. See website or join our email Newsletter for all the latest news.

4-Channel Serial Port Temperature Monitor & Controller Relay Board

4 channel computer serial port temperature monitor and relay controller. Four inputs for Dallas DS18S20 or DS18B20 digital thermometer sensors (£3.95 each). Four 5A rated relay outputs are independent of sensor channels allowing flexibility to setup the linkage in any way you choose. Simple text string commands for reading temperature and relay control via RS232 using a comms program like Windows HyperTerminal or our free Windows application.
*Kit Order Code: 3190KT - **£84.95***
*Assembled Order Code: AS3190 - **£99.95***

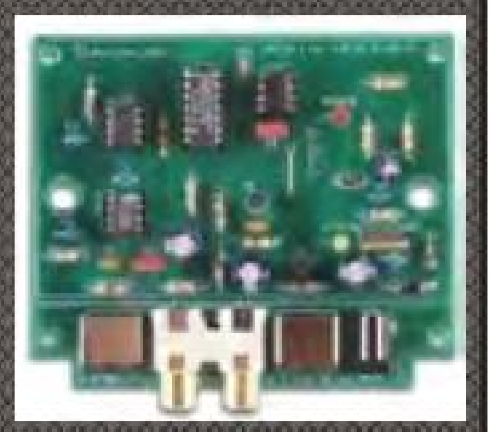
40 Second Message Recorder

Feature packed non-volatile 40 second multi-message sound recorder module using a high quality Winbond sound recorder IC. Standalone operation using just six onboard buttons or use onboard SPI interface. Record using built-in microphone or external line in. 8-24Vdc powered. Change a resistor for different recording duration/sound quality. Sampling frequency 4-12 kHz. (120 second version also available)
*Kit Order Code: 3188KT - **£29.95***
*Assembled Order Code: AS3188 - **£37.95***

Bipolar Stepper Motor Chopper Driver

Get better performance from your stepper motors with this dual full bridge motor driver based on SGS Thompson chips L297 & L298. Motor current for each phase set using on-board potentiometer. Rated to handle motor winding currents up to 2 Amps per phase. Operates on 9-36Vdc supply voltage. Provides all basic motor controls including full or half stepping of bipolar steppers and direction control. Allows multiple driver synchronisation. Perfect for desktop CNC applications.
*Kit Order Code: 3187KT - **£39.95***
*Assembled Order Code: AS3187 - **£49.95***

Video Signal Cleaner



Digitally cleans the video signal and removes unwanted distortion in video signal. In addition it stabilises picture quality and luminance fluctuations. You will also benefit from improved picture quality on LCD monitors or projectors.
*Kit Order Code: K8036 - **£24.70***
*Assembled Order Code: VM106 - **£36.53***

Motor Speed Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

DC Motor Speed Controller (100V/7.5A)

Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H.
*Kit Order Code: 3067KT - **£19.95***
*Assembled Order Code: AS3067 - **£27.95***

Bidirectional DC Motor Speed Controller

Control the speed of most common DC motors (rated up to 32Vdc/10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections.
*Kit Order Code: 3166v2KT - **£23.95***
*Assembled Order Code: AS3166v2 - **£33.95***

Computer Controlled / Standalone Unipolar Stepper Motor Driver

Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.
*Kit Order Code: 3179KT - **£17.95***
*Assembled Order Code: AS3179 - **£24.95***

Computer Controlled Bi-Polar Stepper Motor Driver

Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm.
*Kit Order Code: 3158KT - **£24.95***
*Assembled Order Code: AS3158 - **£34.95***

AC Motor Speed Controller (600W)

Reliable and simple to install project that allows you to adjust the speed of an electric drill or 230V AC single phase induction motor rated up to 600 Watts. Simply turn the potentiometer to adjust the motors RPM. PCB: 48x65mm. Not suitable for use with brushless AC motors.
*Kit Order Code: 1074KT - **£15.95***
*Assembled Order Code: AS1074 - **£23.95***

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Teach-In 2014 Raspberry Pi – Part 2

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CLASSiC-D AMPLIFIER
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FEATURES • Jump Start – Egg Timer • Techno Talk • PIC N' Mix • Circuit Surgery • Interface • Max's Cool Beans • Net Work

MAY '13

PROJECTS • Electronic Stethoscope • PIC/AVR Programming Adaptor Board – Part 1 • Cheap, High-Current Bench Supply • Ingenuity Unlimited

FEATURES • Jump Start – Signal Injector Probe • Techno Talk • Raspberry Pi • PIC N' Mix • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work

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PROJECTS • 6-Decade Capacitance Substitution Box • Soft Starter For Power Tools • High Power Brushless Motors From Old CD/DVD Drives • High-Current Adaptor For Scopes And DMMs

FEATURES • Jump Start – Temperature Alarm • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work

AUG '13

PROJECTS • Driveway Sentry • Milliohm Meter Adaptor For DMMs • Build A Vox • Superb Four-Channel Amplifier – On The Cheap

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SEPT '13

PROJECTS • Digital Sound Effects Module • USB Stereo Recording & Playback Interface • Vacuum Pump From Junk • Minireg 1.3-22V Adjustable Regulator • Ingenuity Unlimited

FEATURES • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work • Computer Error: Reliable Digital Processing – Part 2

OCT '13

PROJECTS • LED Musicolour – Part 1 • High-Temperature Thermometer/Thermostat • Ingenuity Unlimited

FEATURES • Teach-In 2014 – Part 1 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work • Computer Error: Reliable Digital Processing – Part 3

NOV '13

PROJECTS • CLASSiC-D Amplifier – Part 1 • LED Musicolour – Part 2 • Mains Timer For Fans Or Lights • Ingenuity Unlimited

FEATURES • Teach-In 2014 – Part 2 • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work

DEC '13

PROJECTS • Six Test Instruments In One Tiny Box • Virtins Technology Multi-Instrument 3.2 • CLASSiC-D Amplifier – Part 2 •

FEATURES • Teach-In 2014 – Part 3 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work

JAN '14

PROJECTS • 2.5GHz 12-Digit Frequency Counter With Add-on GPS Accuracy – Part 1 • The Champion Amplifier • Simple 1.5A Switching Regulator •

FEATURES • Teach-In 2014 – Part 4 • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work • PIC N' Mix • Net Work

FEB '14

PROJECTS • High-energy Electronic Ignition System – Part 1 • Mobile Phone Loud Ringer! • 2.5GHz 12-Digit Frequency Counter With Add-on GPS Accuracy – Part 2

FEATURES • Teach-In 2014 – Part 5 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work • PIC N' Mix • Net Work

MAR '14

PROJECTS • Infrasound Detector • Extremely Accurate GPS 1pps Timebase For A Frequency Counter • High-energy Electronic Ignition System – Part 2 • Automatic Points Controller For Your Model Railway Layout

FEATURES • Teach-In 2014 – Part 6 • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work • PIC N' Mix • Net Work

APR '14

PROJECTS • Jacobs Ladder • Deluxe GPS 1pps Timebase For Frequency Counters • Capacitor Discharge Unit For Twin-Coil Points Motors

FEATURES • Teach-In 2014 – Part 7 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work • PIC N' Mix • Net Work • Beta-Layout's Re-Flow Oven Kit And Controller review

MAY '14

PROJECTS • Rugged Battery Charger • CLASSiC-D ±35V DC-DC Converter • Digital Multimeter Auto Power-Down • Control Relays Over The Internet With Arduino

FEATURES • Teach-In 2014 – Part 8 • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work • PIC N' Mix • Net Work •

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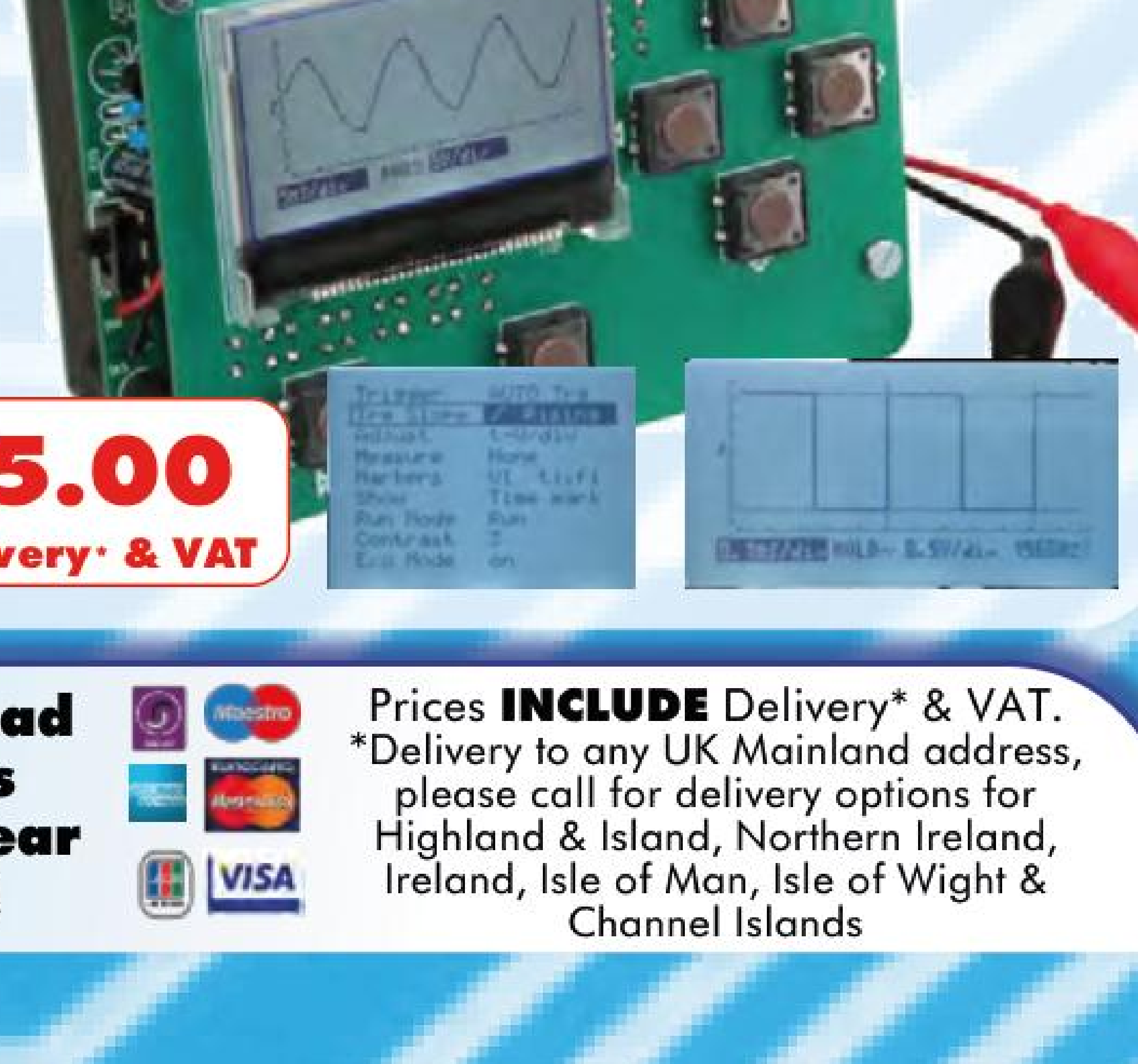
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A number of projects and circuits published in EPE employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

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Kickstarter success

I've mentioned Kickstarter projects (**kickstarter.com**) in the news, but this month it's been 'promoted' to the editorial page thanks to the ingenuity and generosity of *EPE's PIC n' Mix* regular columnist Mike Hibbett. He has made a superb PIC development board that should be of great interest to any *EPE* reader who'd like to add some compact and powerful 'smarts' to their projects. I said 'generosity' because the type of project Mike has produced takes weeks of work, and he has deliberately pitched his circuit at the bargain price of just a tenner. (Even with production in China it's hard to believe there is any margin there at all.) Kickstarter gave Mike 45 days to reach his production goal of £1100, but thanks to *EPE* readers he hit the mark in just four days, and another two days after that he'd achieved 130 per cent of his target.

The project is called the 'Low Power, Low Cost PIC18 Development Board'. While there are plenty of other development boards out there on the market, this one is special – to paraphrase Mike's own description, he has focused on four key areas:

Low power – a circuit that can run off a couple of AA batteries for years
Low cost – it's cheap, if you need another one, just buy it – no need to cannibalise a previous project
Powerful – it has lots of code space and uses a proper, professional development environment
Small – it's tiny, petite enough to be used for wearable computing.

Mike sees this board as a stepping stone to even smaller, more powerful designs, and I look forward to great things in future Kickstarter campaigns. If you want to see for yourself what all the buzz is about, then head over to **kickstarter.com** and search for 'LPLC Board'. I hope you'll be tempted to order one for yourself.

Mike isn't the only *EPE* author with a Kickstarter project. Max Maxfield has launched a very useful Arduino prototyping shield. It's also well worth supporting – see this month's *Max's Cool Beans* column for details.

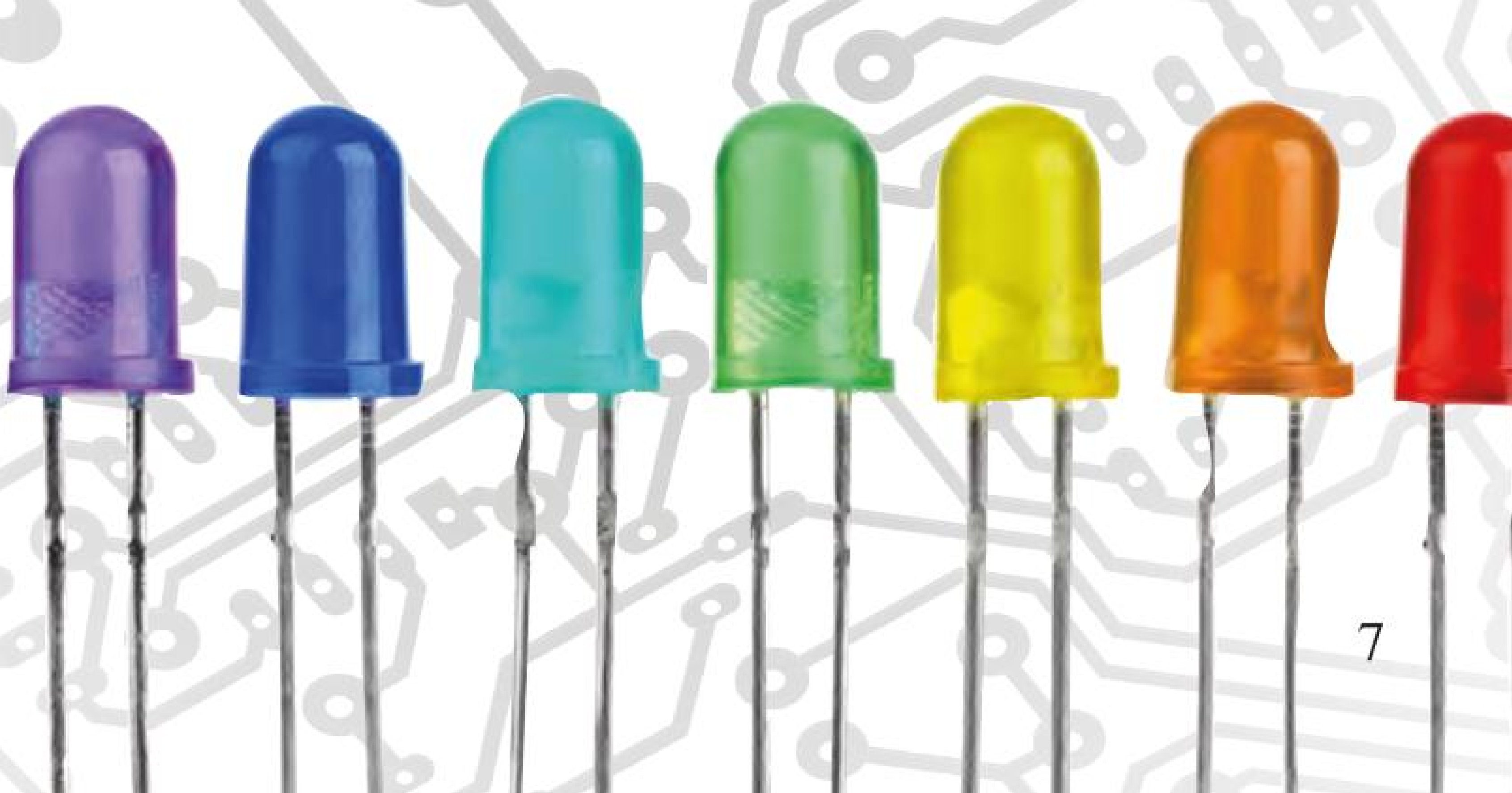
One last thought, if any readers have launched a product on Kickstarter then it would be great to hear from you. Please drop me a line detailing lessons learnt, advice and encouragement for those considering the leap into a product launch.

All you need to know about gas soldering irons

From projects to publishing: *Net Work* guru Alan Winstanley has brought out a companion to his popular Kindle ebook, *The Basic Soldering Guide* with *Introduction to Gas Soldering Irons* (ASIN: B00J4Y3NSY, or just search for 'Alan Winstanley' at **amazon.co.uk**).

Alan explains how popular types of gas-powered soldering iron work, with some butane basics worth knowing, plus essential safety and usage warnings to bear in mind. The new, illustrated ebook also compares various gas soldering irons to highlight key considerations when investing in this handy tool.

You don't have to own an Amazon Kindle to read Alan's ebooks, free Kindle ebook readers for PC, Mac and smartphones are available from the Amazon website.



NEWS

A roundup of the latest Everyday News from the world of electronics

4k gets the Panasonic treament – report by Barry Fox

Most of the big household names in TV – such as Hitachi, Toshiba, Grundig and JVC – have now quit the business in the face of cost-cutting competition from Korean giants LG and Samsung. Philips has sold out to Chinese giant TPV, and Sony is re-structuring its business. Only Panasonic remains in the game.

Enter the Panasonic dragon

Panasonic has now unveiled a range of sub-£2k 4k Ultra HD Viera-connected TVs, with a clever new technical design. The model AX802 sets for sale in the UK will have a unique combination of features, exclusive to Panasonic for an undisclosed period. These include: the World Cup; dual digital terrestrial tuners for the UK's Freeview free-to-air service, dual digital satellite tuners for the UK's Freesat free-to-air services, and the Freetime rollback Electronic Program Guides (EPG), which was designed for use in Freesat satellite set top boxes, but has now been integrated into Panasonic's TVs and extended to cover both Freeview and Freesat.

Panasonic engineers in Cardiff, in collaboration with the BBC and ITV (who jointly own Freesat) did the development work. Set manufacture is at Pilsen in the Czech Republic. The EPG shows broadcast programmes past, present and future, and when users select a past broadcast they are taken to the appropriate one of several catch-up TV services run by the broadcasters: iPlayer from the BBC, ITV Player from ITV, 4oD from Channel 4 and Demand 5 from Channel 5. These services currently offer a total of 26 catch-up channels.

Panasonic's slick 4k Viera TX-65AX800E Ultra HD LED TV

The choice between terrestrial and satellite broadcast reception lets viewers get more channels (200) if they have a satellite dish. Also, some parts of the UK, notably on the South Coast near France, suffer breakthrough interference to Freeview but not Freesat. Dishes installed for Sky Pay satellite TV, but no longer used for Sky, can be connected to the TV satellite tuner.

LED/LCD, not plasma

The Panasonic sets have LCD screens with locally dimmed LED backlights, rather than plasma display panels. Panasonic says it knows it set the benchmark for black blacks after buying Pioneer's Kuro technology and design team, but could not manufacture them at affordable prices.

Says Panasonic UK managing director Andrew Denham; 'We now have to beat plasma with LED'. The Panasonic 4k system uses new HDMI 2.0 chips to handle full resolution 4:2:2 or 4:4:4 colour, rather than the compromise 4:2:0 system adopted by Sony to allow the firmware upgrading of HDMI 1.4 chips in older sets.

The Panasonic TVs also have a heat sensor to detect when someone is in the room and a built-in (but physically blockable) camera with face detection to know who they are and their favourite channels.

The AX802 range will be available from April in 50in, 58in and 65in screen sizes, with prices targeted to start below £2000.

Cyberlink news

The latest version of Cyberlink PowerDVD 14 – released April 8 worldwide – claims to be the first multimedia player software with inbuilt support for the new High Efficiency Video Coding format, HEVC/H.265. The HEVC format is around 50% more efficient than MPEG.4/H.264, as currently used for HDTV and Bluray, and is employed for 4k Ultra HD because HEVC halves the number of bits that must be stored or broadcast, and thus also halves download times. The same bit-saving benefits apply when HEVC is used for HD.

UltraViolet included

Along with HEVC support, and a bewildering clutch of 50 other new and enhanced features, PowerDVD 14 will also support the UltraViolet Digital Locker system in countries such as the US and UK where UV is available. It recognises the new Common File Format Option adopted by DECE, the Digital Entertainment Content Ecosystem group. Users will be able to download UV video files, with the extension label **.uvu**, direct from a UV Cloud locker, and play them on a PC or device with PowerDVD installed.

PowerDVD 14 also has the ability to 'pin' or download and save online movie clips from YouTube for offline playback. This lets the user control download data costs and watch a clip with smooth playback when data speeds are low or erratic. 'Pinning' also lets the user use Cyberlink software to enhance quality, for instance upscale SD to HD or reduce video noise, or convert a 2D clip to 3D. Cyberlink likens PowerDVD to a DVR for YouTube because playback can be slowed or fast-forwarded.

Cyberlink is offering PowerDVD 14 either for purchase or 'Live' on subscription, with prices for the full version £80 for a perpetual licence or £35 for a year's subscription.

A leg up for bootleggers?

Following the model adopted by Adobe for new versions of Photoshop, the new version of Cyberlink Director Suite multimedia editing software is available only 'Live' – by subscription at £40 per quarter or £80 per annum, with 10GB of content for storage free, and extra space available at additional cost.

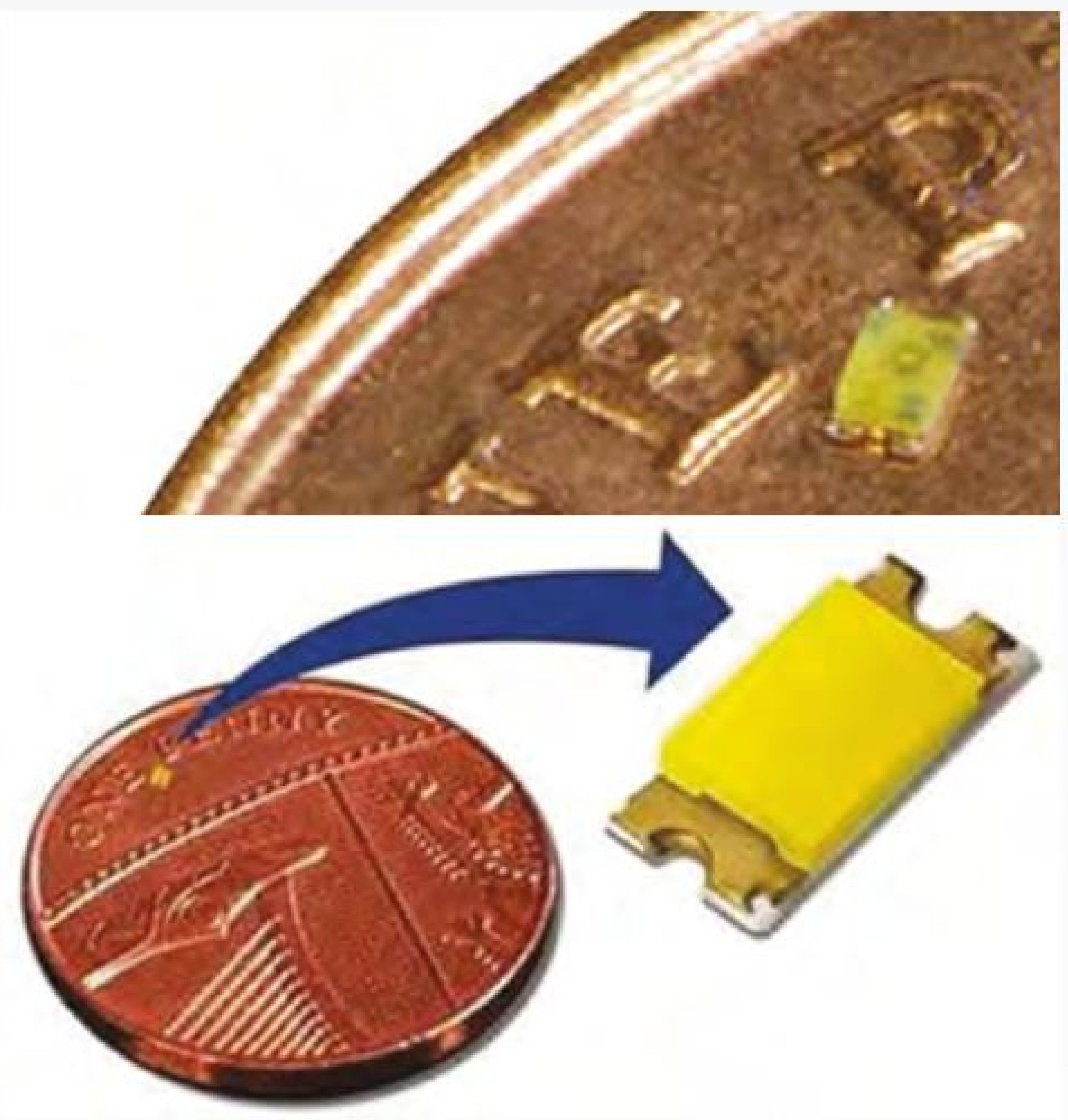
Director Suite now incorporates what might be called a 'boon to concert bootlegger' function; it lets several people with video cameras or phones independently shoot the same musical performance from different angles, and later combine their best shots into a single linear movie – without the need for synchronising time code as generated by professional cameras.

Ideally, the performance is captured in high quality audio from start to finish by an audio recorder or single camera with good microphone, as well as by several independent cameras. During editing the Director Suite software compares the audio recorded by the various other video cameras and locks their capture streams together for cutting from one video source to another.

If there is no linear master audio recording available, the software time-aligns whatever audio has been captured by the various cameras, to allow cross cutting between them without loss of lip sync.

Plessey launches dotLED for wearable electronics market

UK-based manufacturer Plessey has announced the launch of its smallest packaged MaGIC LED, aimed at the surging wearable electronics market. The PLW138003 is a white LED in a 1005 SMT package designed specifically for the demand for ever-smaller LED components producing highly collimated light. Plessey's dotLEDs weigh just 0.2 milligrams and have a profile of 0.2mm. Further additions to the dotLED family will be colour variants and a series in the larger 1608 footprint.



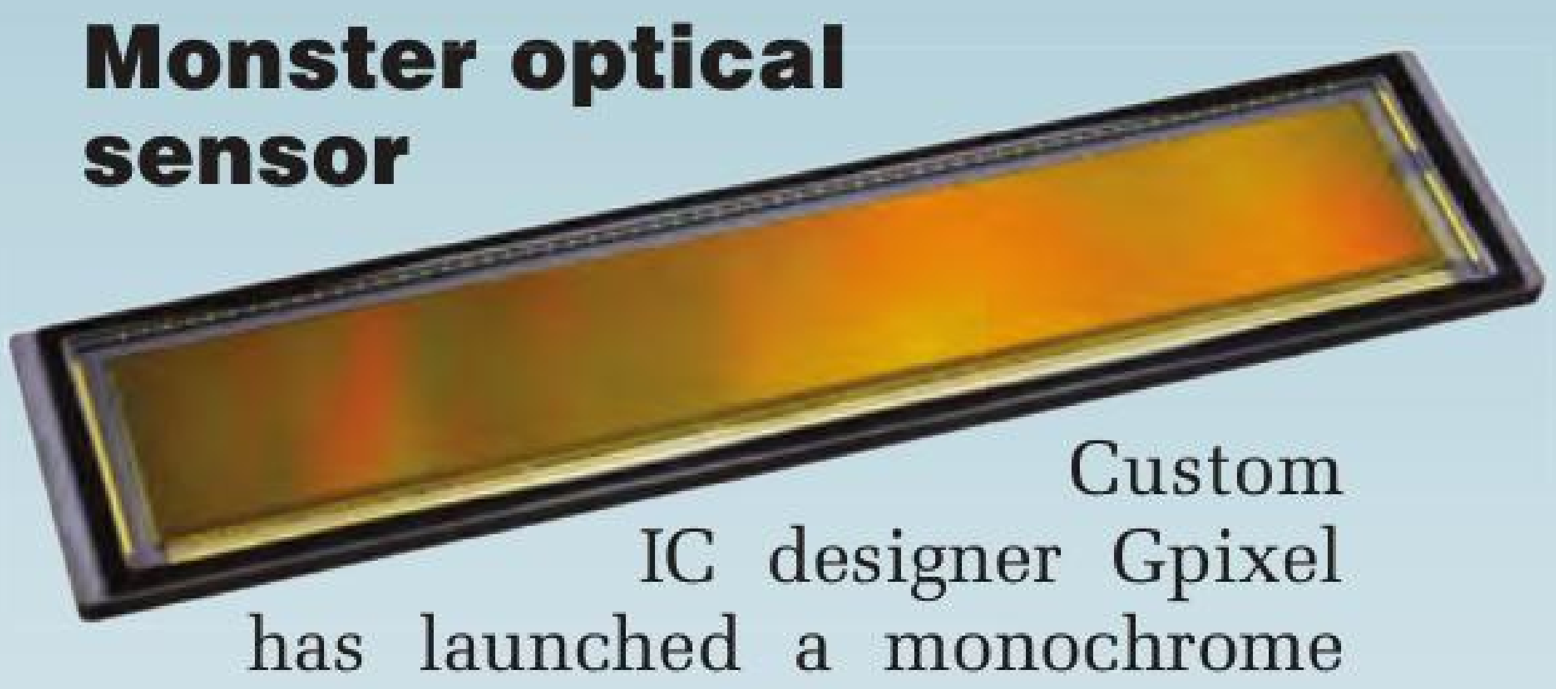
New magnets

For 30 years, the now-classic recipe of Nd-Fe-B (neodymium, iron and boron) has been the mainstay of high power magnet design. From tiny speakers in headphones to megawatt wind turbine generators, Nd-Fe-B magnets have revolutionised and improved many engineering sectors.

The key ingredient is neodymium, a so-called 'Rare Earth' element. In fact, Rare Earths are not that rare, but they are tricky to extract and the process can be very polluting. So polluting that most Western countries, notably the US, gave up production. This handed almost all of the market to China, and now, somewhat late in the day, the US has realised that it lacks control of a strategic mineral.

In response, the US Department of Energy has launched the REACT (rare-earth alternatives in critical technologies) programme, to develop new kinds of permanent magnets that do not need unusual minerals and which can survive high temperatures. The proposed materials innovation is expected to lead to substantial cost reduction in many areas of manufacturing – for example, wind turbine generators, where replacing Nd-Fe-B magnets will also help to reduce the need for expensive active cooling systems.

Monster optical sensor



Custom IC designer Gpixel has launched a monochrome CMOS image sensor, offering a world record 150MP active pixel resolution, and capable of running at ten frames per second at full frame with even higher frame rates achieved in row-windowing mode. This 'wafer-scale' sensor has an astonishing 167.6mm × 30.1mm chip size, including a 165mm × 27.5mm photon-sensitive area. The sensor includes a 16-bit on-chip ADC and consumes less than 2.5W at full frame rate in full resolution. The device is targeted at the most demanding medical, industrial and scientific imaging markets.

Sony/Panasonic develop next-gen optical discs

Sony and Panasonic have agreed to jointly develop the next generation of professional-use optical discs, with the objective of expanding their archive business for long-term digital data storage. Both companies will target the development of an optical disc with recording capacity of at least 300GB by the end of 2015.

Optical discs have excellent properties to protect them against the environment, such as dust-resistance and water-resistance, and can also withstand changes in temperature and humidity when stored. They also allow inter-generational compatibility between different formats, ensuring that data can continue to be read even as formats evolve.

In recent years, there has been an increasing need for archive capabilities, not only from video production industries, such as motion pictures and broadcasting, but also from cloud-based data centers that handle increasingly large volumes of data following the evolution in network services.

Net overload

A recent seminar at the University of Bristol has predicted that by the year 2020, over seven trillion devices would be connected to the global mobile network, and that the current 3G and 4G mobile technology will simply not be able to cope. Approaching 1000 devices for each and every person on the earth, the seminar called for funding and research to meet this challenge.

Cranial Electrical Stimulation Unit

By ROBERT SCOTT

CRANIAL ELECTRO STIMULATOR
FLOW INDICATORS
NEG
POS
LO
LEVEL
OUTPUT
RATE
ON
OFF

Commercial cranial electrical stimulation (CES) units cost hundreds of pounds, but this one is cheap and easy to build. It is battery-powered, portable and has adjustable current delivery and repetition rate.

NO, THIS IS NOT a do-it-yourself electroshock therapy project. The voltage and current used for 'cranial electrical stimulation' (CES, also known as 'transcranial electrotherapy or neuroelectric therapy') is very low, ensuring that it is safe for the recipient. It does not cause a 'shock' sensation or a lot of pain, although it can result in 'pinpricks' at the higher settings. However, at the voltage and current levels involved with this project there is no risk of injury.

We are not doctors so we cannot say whether CES is beneficial. Some claim that it reduces anxiety, treats pain (especially headaches) and promotes alertness and relaxation. If you have investigated the potential benefits and would like to try CES, building this project is a cheap and easy way to do so.

We can't rule out the possibility that the benefits from CES are a placebo effect but if true, such benefits are still real. If so, it would be a case of 'mind over matter!'

What is CES?

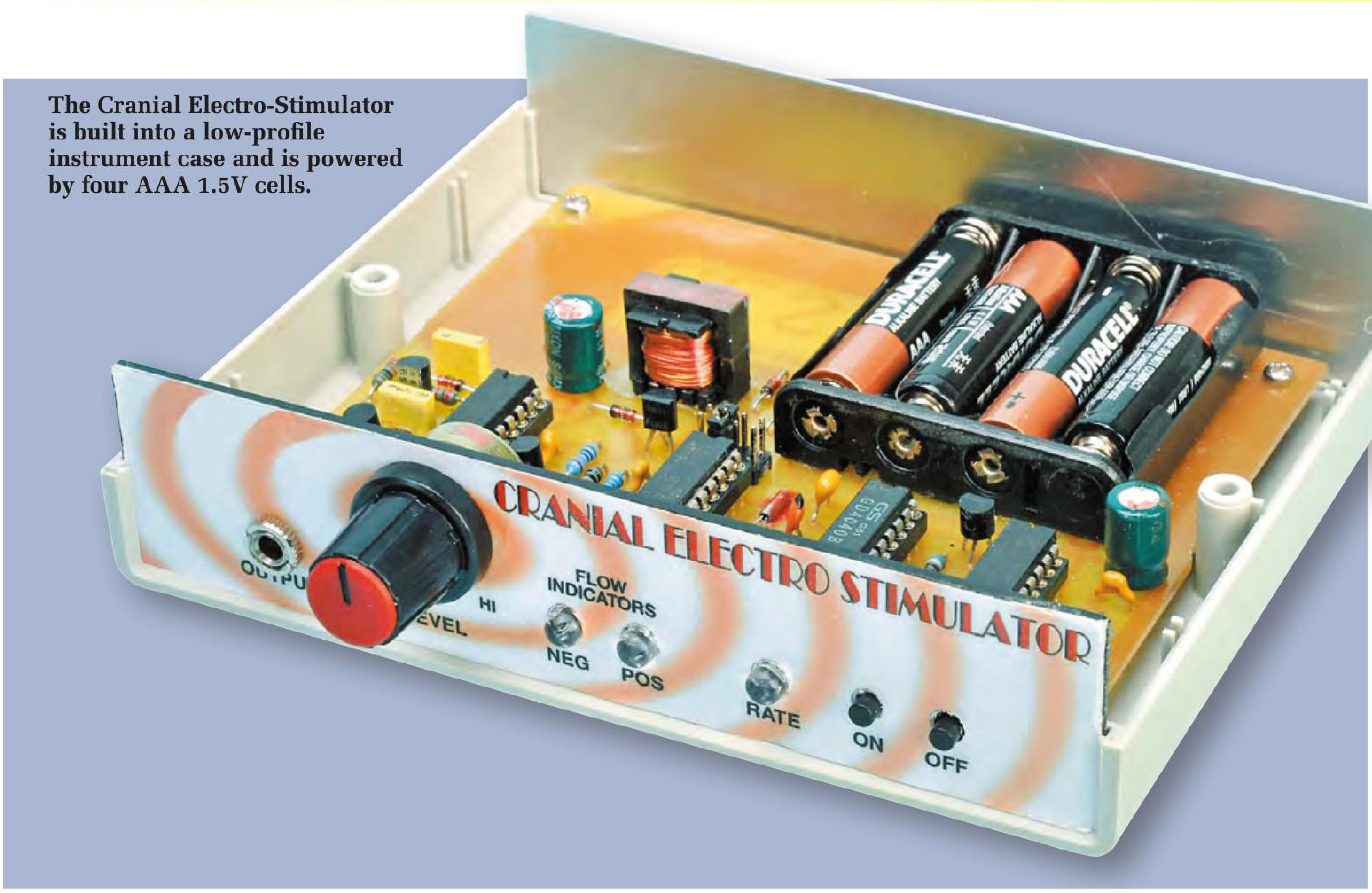
CES involves passing a small amount of current through the recipient's head. A proportion of this is thought to pass through the brain and create chemical changes which may influence mood.

Obviously we must be careful to limit the amount of power that can pass through a sensitive organ like the brain. In this case, the current is limited to a maximum of half a milliamp (0.5mA) and the voltage is limited to 15V. Since the unit is powered from a small battery (four AAAs) rather than mains, there is no possibility that a fault could result in a fried noggin!

Commercial CES devices vary, but generally deliver somewhere between 0.01mA to 1mA with a repetition rate between 0.5Hz and 100Hz. With this unit, both parameters can be adjusted, so you can find the combination that works best for you.

The Transcutaneous Electrical Nerve Stimulation or TENS unit published in *EPE*, September 2007 is similar in some respects. That unit also relied on electrical stimulation of the human body, but at higher voltage and current levels. However, as stated in the TENS article, these levels are unsuitable for use on the head or neck, so this CES unit has been designed to deliver much less power in order to make it even safer.

Current is delivered to the patient via clip-on leads that attach to the ear lobes. While at first it may seem



The Cranial Electro-Stimulator is built into a low-profile instrument case and is powered by four AAA 1.5V cells.

unlikely that just 15V can result in current conduction through the human body, the ear tingling and (at higher settings) pin-prick sensation demonstrates that a circuit is indeed made. Just how much current is flowing is indicated by the brightness of two LEDs on the front panel.

For further evidence that a voltage this low can cause current to flow through the human body, set a DMM to ohms mode and hold a probe in each hand. This will show your own body's resistance, which varies depending on the amount of moisture on your hands. You should find that holding the probes behind your ears results in a similar reading. Generally speaking, you will find it is below 1MΩ.

Circuit description

Take a look now at Fig.1 for the circuit details. It's based on four CMOS digital logic ICs and a handful of other parts. The ICs are readily available and since the circuit is based entirely on discrete logic, there is no need for a microcontroller.

IC3 and IC4 form the on/off switch logic and session timer. They also flash the 'RATE' LED at 1Hz to indicate that the unit is operating. IC3 is a 4011 quad 2-input NAND gate and IC4 is a 4040 12-stage binary counter.

IC3a and IC3b together make an RS flip-flop. Pin 1 is its Reset input and pin 6 is its Set input. When pin 1 is pulled low (ie, button S1 is pressed), the output at pin 4 goes low and when pin 6 is pulled low (ie, button S2 is pressed) it goes high.

When the ON button (S1) is pressed, the output of the flip-flop goes low, and this turns PNP transistor Q1 on. As long as Q1 remains on, power from the battery can flow to the rest of the circuit. Pressing S1 also resets IC4 (via IC3d), starting the session timer.

The 10kΩ pull-up resistor and 100nF capacitor across S1 form a filter, which debounces the button press and also ensures that the device is off initially when the batteries are installed. Note that IC3 is permanently connected to the battery, but since it draws well under 1μA, its current draw is less than the cells' self-discharge current.

IC4's clock input (pin 10) is driven at 2Hz (by pin 3 of IC1) so after 25 minutes of operation, outputs O10 and O11 (pins 15 and 1) of timer IC4 both go high. As a result, IC3c's output goes low, pulling down pin 6 of IC3b, which has the same effect as pressing the OFF button (S2). As a result, the

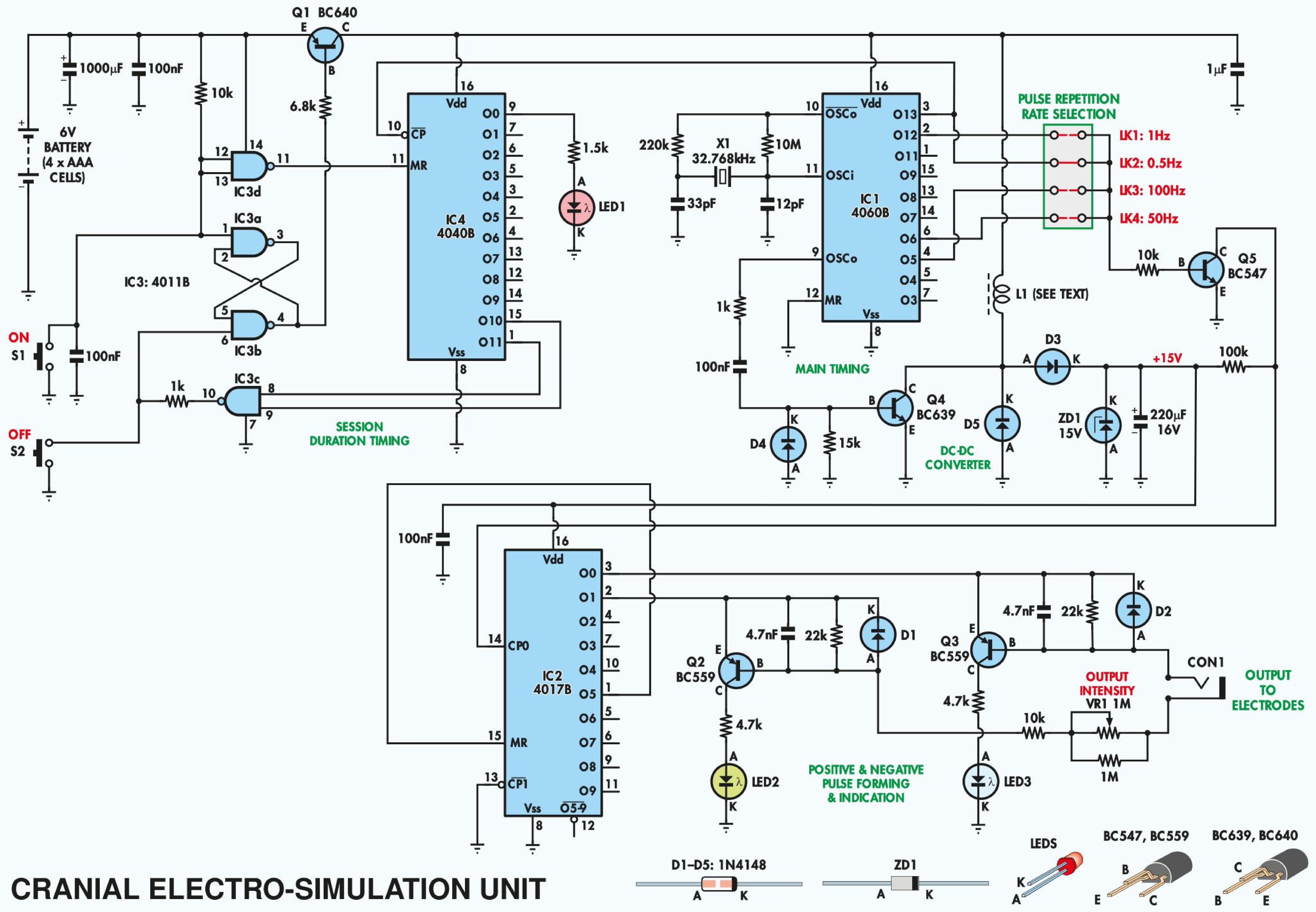
Main features

- Adjustable current (0.03-0.5mA)
- Adjustable repetition rate (0.5-100Hz in four steps)
- Battery powered
- Portable
- Flashing activity LED
- Automatic turn-off timer (25 minutes) which can be reset
- LEDs indicate level of intensity of stimulation
- Long battery life (up to 100 hours continuous operation)

Warning!

(1) This unit (or any other similar device) must not be used on a person who has a heart pacemaker or other implanted electronic device.

(2) Do not be tempted to run this unit from a mains adaptor, plugpack or power supply. This could be dangerous if a breakdown occurs in the isolating transformer.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C
B
6.8k
1000µF
100nF
10k
6V
BATTERY
(4 x AAA
CELLS)
IC3d
IC3a
IC3b
IC3c
IC3: 4011B
ON
S1
OFF
S2
100nF
1k
SESSION
DURATION TIMING
IC4
4040B
Vdd
CP
MR
Vss
O0
O1
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O3
O4
O5
O6
O7
O8
O9
O10
O11
1.5k
LED1
220k
X1
32.768kHz
10M
33pF
12pF
IC1
4060B
OSCo
OSCi
MR
O13
O12
O11
O9
O8
O7
O6
O5
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CRANIAL ELECTRO-SIMULATION UNIT

Fig.1: the circuit is based on four low-cost CMOS ICs. Quad NAND gate IC3 and 12-stage binary counter IC4 form the on/off switch and session timer, while 14-stage binary counter IC1 and decade counter IC2 set the pulse repetition rate. IC1 also forms a crystal oscillator (in conjunction with X1) and drives a boost converter based on Q4, inductor L1 and their associated diodes to produce a +15V rail.

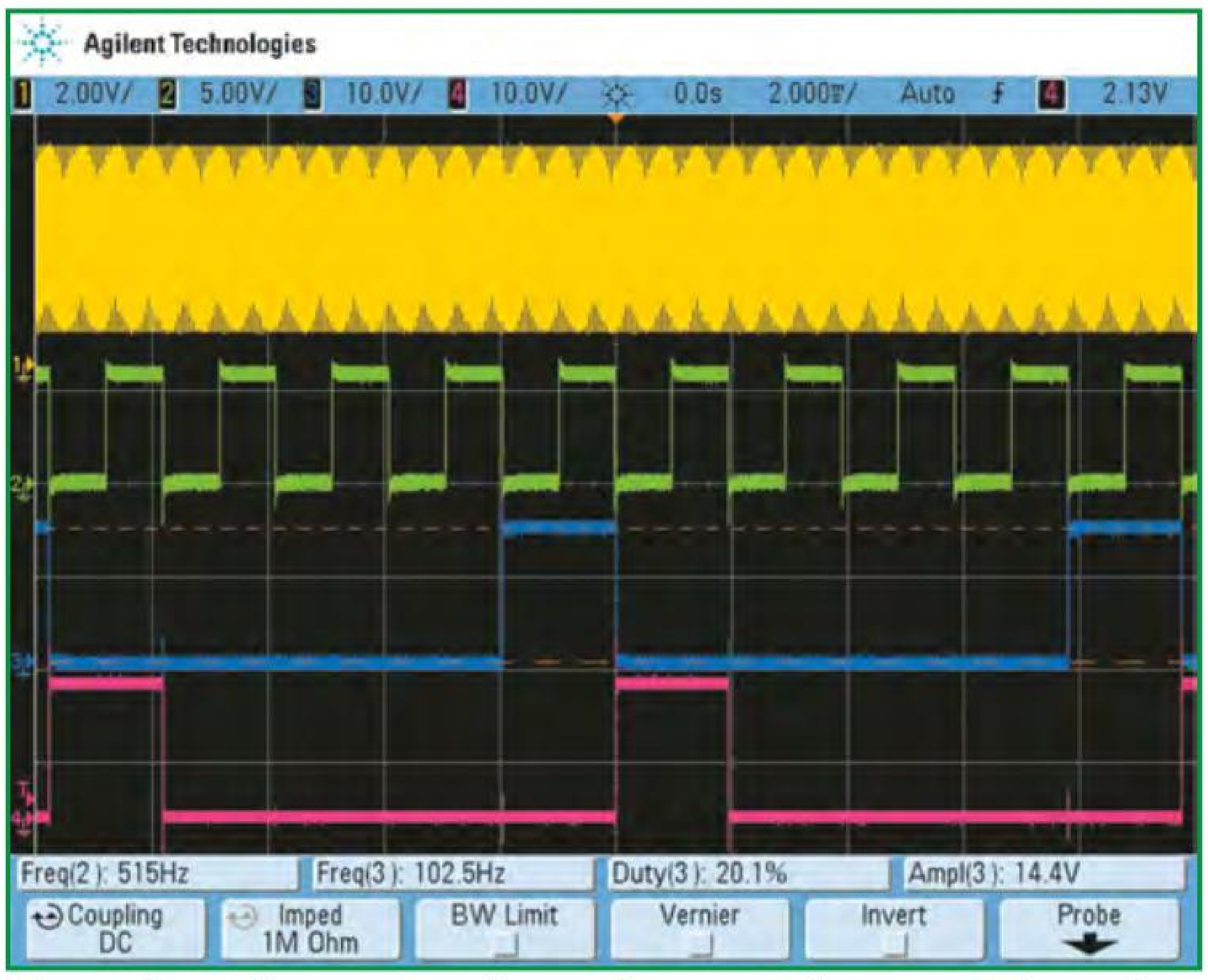


Fig.2: the yellow trace shows the 32.768kHz waveform from the crystal oscillator at pin 10 of IC1. Below it, the green trace is the 512Hz signal at pin 4. The two lower traces show the alternating output pulse at pins 2 and 3 of IC2. As can be seen from the measurements, the output frequency is 102.5Hz (nominally 100Hz) and the duty cycle is 20%.

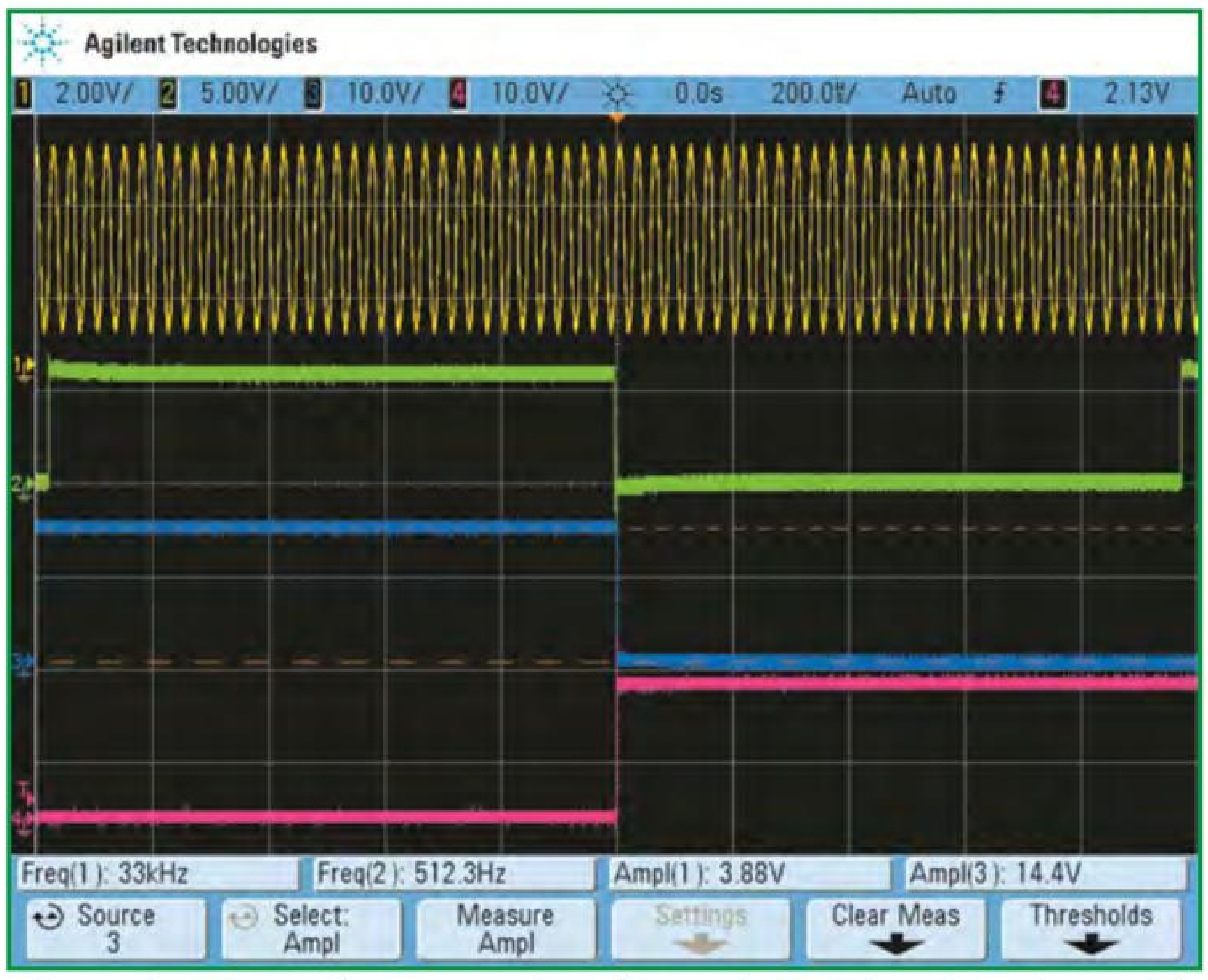


Fig.3: these are the same signals as shown in Fig.2, but with a shorter timebase so that the 32.768kHz sinewave-like oscillation of the crystal is visible. As can be seen, when the first output pulse ceases the second immediately begins, causing a voltage differential across the electrodes. The output amplitude, as shown, is just below 15V

RS flipflop is set and so Q1 turns off, powering down the circuit.

Pulse timing

Pin 9 of IC4 (O0) is the lowest timer output bit, and this toggles at half the input clock rate, flashing high-brightness red LED1 at 1Hz while IC1 is powered. The 2Hz source clock is produced by IC1, a 4060 14-stage binary counter. Pins 10 and 11 of IC1 form a crystal oscillator circuit based on X1, a 32.768kHz watch crystal.

Now, 32,768 is 2^{15}, so a binary counter can derive exact 1Hz pulses from this frequency by halving it 15 times. Since IC1 is a 14-stage ripple counter, it produces a 2Hz output at O13, as well as 4Hz at O12, 8Hz at O11 and so on.

Depending on which of LK1-4 is shorted, one of IC1's clock outputs drives the base of Q5, an NPN transistor which acts as a level shifter. This allows IC1 – which runs from a 6V (nominal) battery – to interface with IC2, which runs off a higher voltage (15V). When Q5 is off, a 100kΩ resistor pulls pin 14 (CP0) of IC2 high to 15V. Conversely, when Q5 is on, that pin is pulled low to 0V.

CP0 is the clock input of IC2, another counter IC. This one is configured to divide its input frequency by five, since its sixth output (O5) is connected to its reset pin (pin 15). Depending on which of LK1-4 is installed, IC2 is driven at 4Hz, 2Hz, 512Hz and 256Hz respectively.

After being divided by five, the result is 0.8Hz, 0.4Hz, 102.4Hz and 51.2Hz. These are the four pulse repetition rate options available, which we round to 1Hz, 0.5Hz, 100Hz and 50Hz for convenience.

Voltage booster

IC1 does double duty by also driving a boost converter based on transistor Q4. Its pin 9 output (which is an inverted version of the clock signal on pin 10) drives Q4's base. This works with inductor L1, diodes D3-D5 and Zener diode ZD1 to generate a nominal 15V rail, which powers IC2 and ultimately provides the cranial stimulation.

In operation, the 32.768kHz square wave from pin 9 of IC1 is AC-coupled to the base of Q4, an NPN transistor with a 1A rating. When the output from pin 9 is high, Q4's base-emitter junction is forward biased and so it 'sinks' current from the battery through L1, a high-value inductor. This charges its magnetic field.

When the output from pin 9 subsequently goes low and Q4 switches off, the collapsing magnetic field causes a voltage spike. This in turn forward biases D3 and charges the 220µF capacitor at its output. The voltage across this capacitor is limited to 15V by ZD1.

D4 protects Q4's base-emitter junction from being reverse biased, while the 15kΩ resistor provides DC bias and ensures a fast switch-off. The 1kΩ series resistor limits the base current.

The advantage of using a boosted supply rather than just more battery cells is reduced size and weight, as well as a consistent voltage for cranial stimulation, even as the battery discharges and its voltage drops.

Electrode drive

As mentioned, IC2 divides its input clock by five. This means each of its O0-O4 output pins is high for 20% of the time and low the remaining 80% of the time. Two of these outputs (O0 and O1) drive the cranial electrodes, while the other three are not connected. As a result, the electrodes are driven alternately, followed by a pause.

Current for the electrodes flows from O0, through the recipient's head and back to O1, or it flows the other way around. When one of these outputs is sourcing current, it passes through a 22kΩ resistor, which provides current limiting. Alternatively, when sinking current, most of the current flows through either diode D1 or D2.

High-brightness LEDs

Transistors Q2 and Q3 drive high-brightness blue and green LEDs to indicate which output is sourcing current and how much is flowing. The more current that passes through one of the 22kΩ resistors, the higher the base-emitter voltage of the associated transistor. These transistors drive high-brightness LEDs. Since the higher base-emitter voltages result in more current flow to these

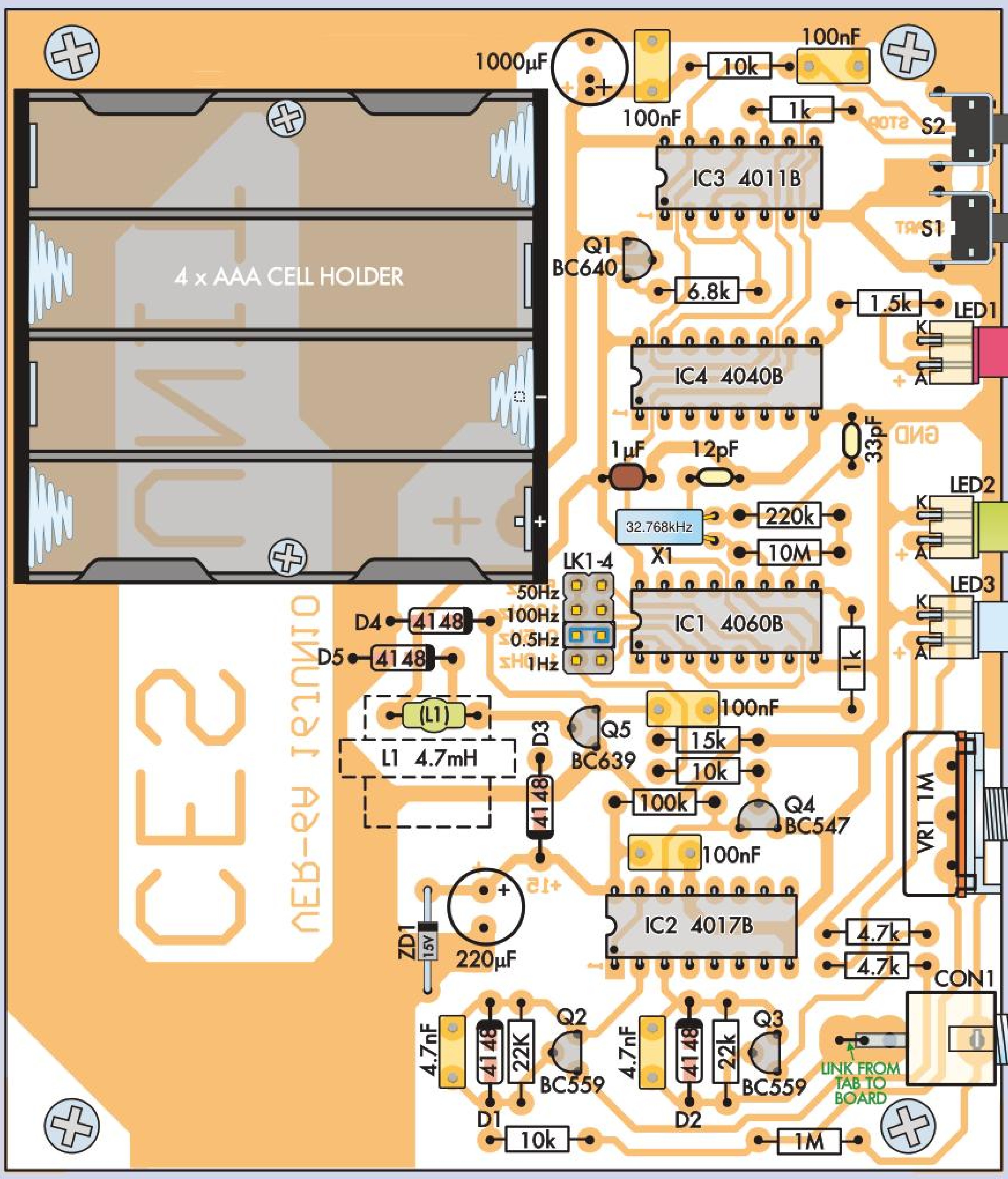

1000µF
100nF
10k
100nF
1k
S2
S1
STOP
START
IC3 4011B
Q1
BC640
6.8k
1.5k
LED1
K
A
IC4 4040B
33pF
GND
1µF
12pF
LED2
32.768kHz
220k
X1
10M
LK1-4
LED3
50Hz
100Hz
0.5Hz
1Hz
IC1 4060B
4 x AAA CELL HOLDER
D4
4148
D5
4148
1k
100nF
(L1)
Q5
BC639
15k
L1 4.7mH
D3
10k
100k
Q4
BC547
4148
VR1 1M
100nF
+15
ZD1
15V
220µF
IC2 4017B
4.7k
4.7k
CON1
CES
VER-04 1810910
4.7nF
4148
22K
Q2
BC559
4.7nF
4148
22k
Q3
BC559
LINK FROM TAB TO BOARD
D1
10k
D2
1M

Fig.4: follow this layout diagram to assemble the PC board. Make sure that all polarised parts are correctly oriented and also be careful not to get the ICs mixed up. The photo below shows the completed prototype.

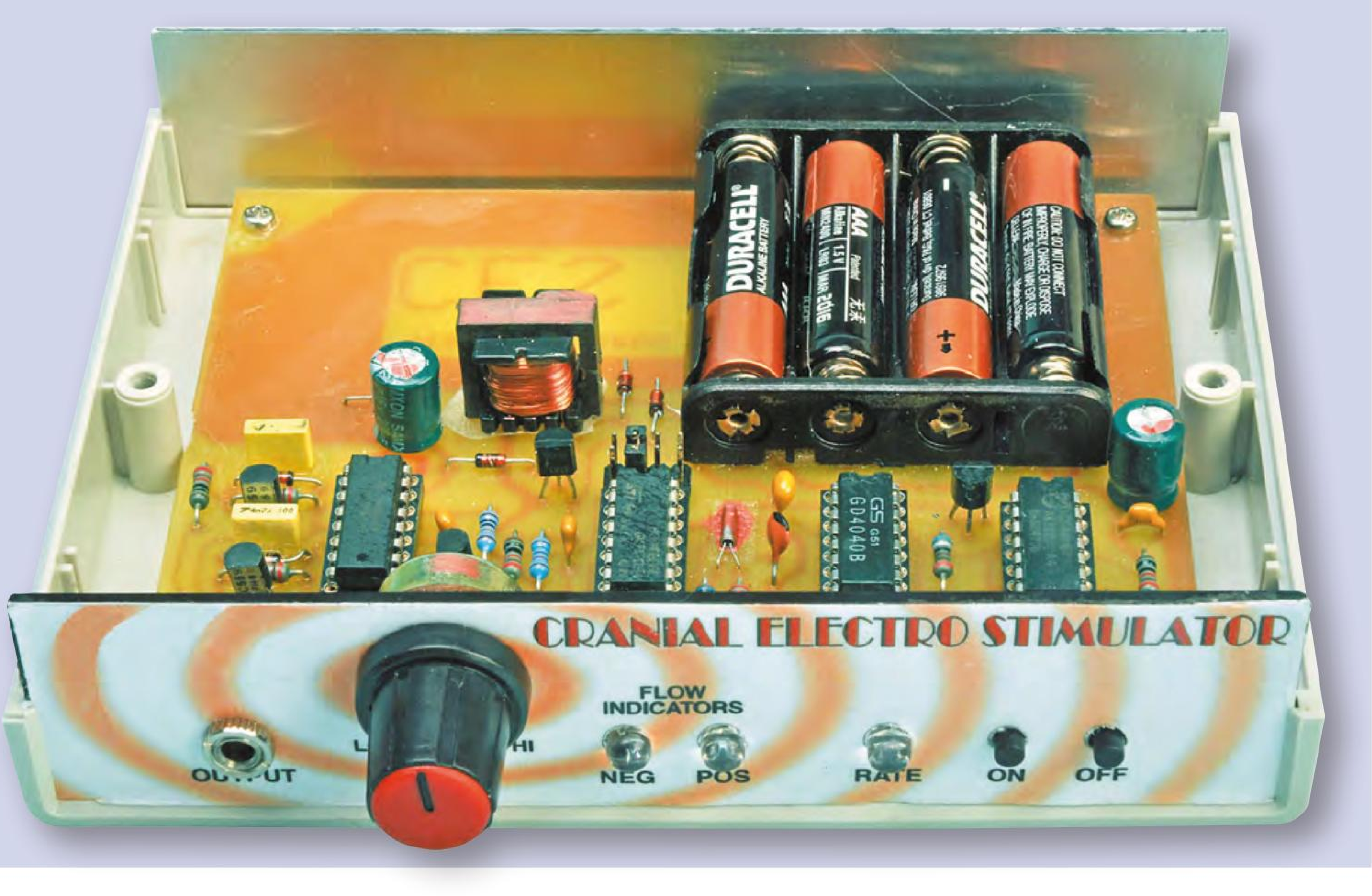
LEDs, they glow brighter. A 4.7nF capacitor across each base-emitter junction prevents AC signals coupled via stray capacitance (primarily within Q2 and Q3) from turning on the LEDs when there is no electrode current.

Note that there is additional resistance between output O1 and the electrodes, compared to the path from O0. This consists of a series 10kΩ resistor and 1MΩ potentiometer (VR1), with a 1MΩ fixed resistor in parallel with the latter. The 10kΩ resistor provides additional current limiting, while VR1 allows the stimulation current to be adjusted from approximately 0.03mA to 0.5mA.

Inductor selection

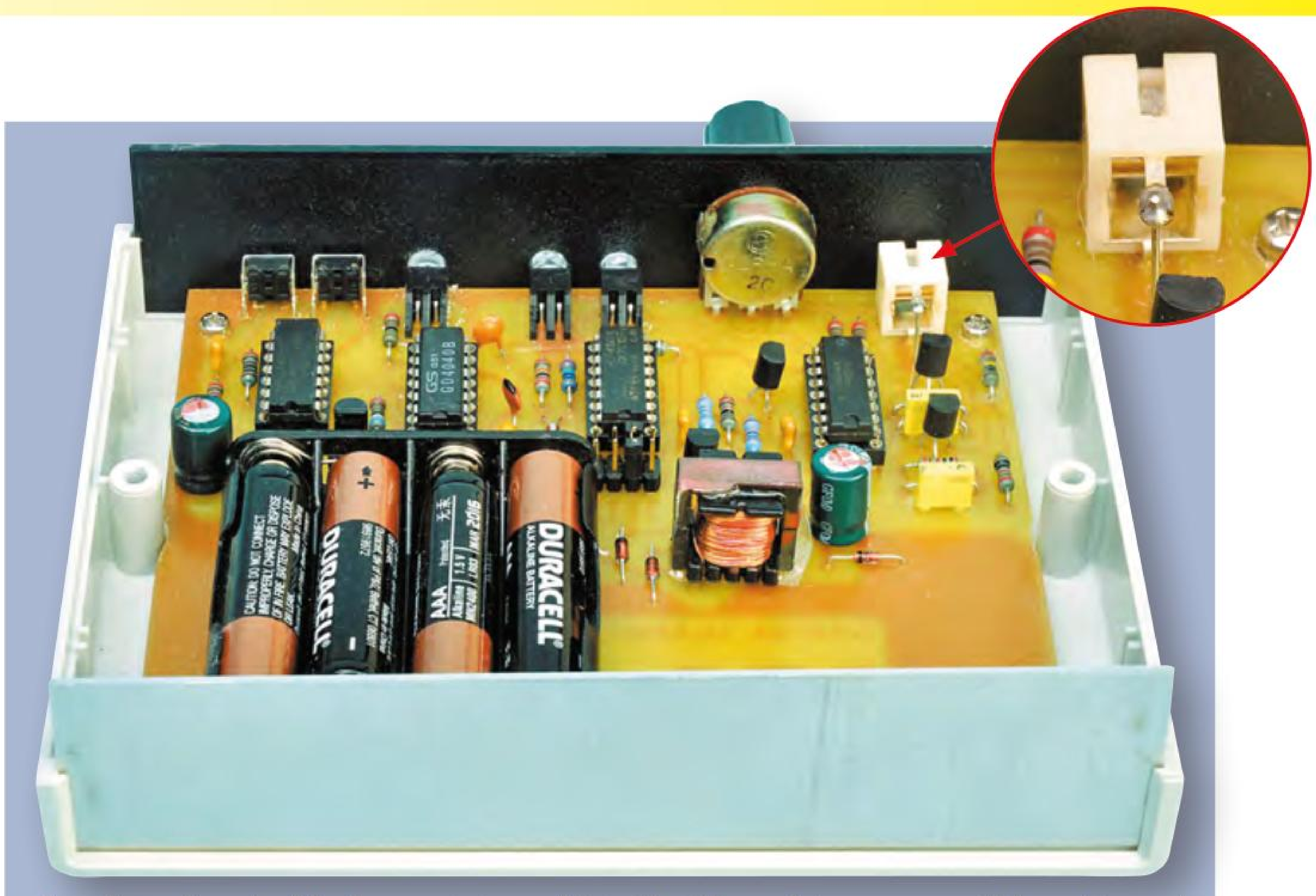
The inductor (L1) used in the prototype was obtained from a non-functioning compact fluorescent lamp (CFL). If you have a faulty 15-20W CFL, you can open it up by clamping the base in a vice and then cutting through the groove in the plastic base using a hacksaw. Chances are it will contain a suitable choke. Be careful not to break the glass tube(s) during this operation.

If you do not have an unserviceable CFL to dismantle, a 4.7mH (or thereabouts) inductor with a current capability of at least 100mA can be


CRANIAL ELECTRO STIMULATOR
FLOW INDICATORS
OU[illegible]UT
L
HI
NEG
POS
RATE
ON
OFF
DURACELL

substituted. Alternatively, if you have an inductance meter, you can wind your own inductor on a ferrite or powdered-iron core – just add turns until the measured inductance is in the appropriate range.

The salvaged inductor in the prototype measured 7mH. The lower the inductance value used, the higher the battery drain when the unit is operating, as the peak current through L1 is higher. A 4.7mH inductor increases the battery current by around 2mA compared to using a 7mH inductor. For this reason, we do not recommend going much lower than 4.7mH.



Another view inside the prototype. Note that for safety reasons, this unit must be powered by four AAA 1.5V cells. Do NOT use a plugpack.

Construction

All the parts are mounted on a single-sided PC board available from the *EPE PCB Service*, coded 99101111 and measuring 118mm × 102mm. Fig.4 shows the assembly details.

Begin by checking the board for any defects, then fit the resistors. Use a digital multimeter (DMM) to check the value of each resistor before installing it. Once they are in, follow with the diodes (D1-D5) and Zener diode (ZD1). Ensure that the striped end of each diode is oriented as shown on Fig.4.

Follow with the ICs, taking care to ensure that each is correctly oriented and that it is installed in the correct location. Alternatively, if you are using sockets (optional) then install them instead. In either case, the notch or dot that indicates pin 1 goes towards the back edge of the board.

Check also that each device is sitting flat on the PC board before soldering its pins. Do not get the ICs mixed up, as they are all different types.

Crystal X1 is next on the list. It doesn't matter which way around it goes. Lay its body flat against the PC board using a small piece of double-sided tape to hold it in place, to avoid stress on the leads.

Next, mount the five transistors (Q1-Q5). There are four different types, so check the marking on each before installing it, to ensure it goes in the right place. Use small pliers to bend the legs outwards at 45° and then back down parallel again so that they fit in the holes on the board. Be sure to orient each one as shown on the overlay.

Now solder the MKT and ceramic capacitors in place, followed by the pin header strip and the two electrolytic capacitors. The electrolytics must be correctly oriented, so be sure to match their positive (longer) leads with the '+' signs on the overlay.

Follow with the two tactile switches, which must be pushed flat against the PC board before being soldered.

The 3.5mm jack socket is not a PC-mount component, so this must be modified before it is installed. First, use pliers to pinch the eyelet holes shut, except for the longer one projecting from the rear of the connector. That done, bend the shorter lead at the rear down at right angles (see photo).

Next, solder a piece of tinned copper wire to the remaining eyelet, making sure it is long enough to go through

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
1µF	1µF	1u0	105
100nF	0.1µF	100n	104
4.7nF	.0047µF	4n7	472
33pF	NA	33p	33
12pF	NA	12p	12

Table 1: Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	10MΩ	brown black blue brown	brown black black green brown
☐	1	1MΩ	brown black green brown	brown black black yellow brown
☐	1	220kΩ	red red yellow brown	red red black orange brown
☐	1	100kΩ	brown black yellow brown	brown black black orange brown
☐	2	22kΩ	red red orange brown	red red black red brown
☐	1	15kΩ	brown green orange brown	brown green black red brown
☐	3	10kΩ	brown black orange brown	brown black black red brown
☐	1	6.8kΩ	blue grey red brown	blue grey black brown brown
☐	2	4.7kΩ	yellow violet red brown	yellow violet black brown brown
☐	1	1.5kΩ	brown green red brown	brown green black brown brown
☐	2	1kΩ	brown black red brown	brown black black brown brown

Parts List For Cranial Electro-Stimulator

- 1 PC board, available from the *EPE PCB Service,* code 99101111, 118mm × 102mm
- 1 ABS instrument case, 140mm × 110mm × 35mm
- 1 PC-mount 4 × AAA battery holder
- 2 right-angle tactile switches
- 1 3.5mm mono phono jack socket
- 1 3.5mm mono phono jack plug
- 1 knob to suit VR1
- 1 4700µH inductor or higher value choke salvaged from a CFL (L1)
- 1 32.768kHz watch crystal (X1)
- 1 2 × 4-pin header, 2.54mm pitch
- 3 16-pin DIL sockets (optional)
- 1 14-pin DIL socket (optional)
- 1 jumper link for pin header
- 1 pair 65mm alligator clips
- 3 right-angle LED mounting blocks
- 4 No.4 × 6mm self-tapping screws
- double-sided tape
- 100 × 12 × 0.127mm (0.005-inch) brass sheet
- 1 2m-length twin core cable
- 25mm 0.71mm diameter tinned copper wire
- 25mm heatshrink tubing, 5mm diameter
- 1 front panel label
- 1 1MΩ 16mm linear potentiometer (VR1)
- 2 M2 × 5mm machine screws and nuts

Semiconductors

- 1 CD4060/HEF4060 14-stage ripple counter (IC1)
- 1 CD4017/HEF4017 decade counter/divider (IC2)
- 1 CD4011/HEF4011 quad 2-input NAND gate (IC3)
- 1 CD4040/HEF4040 12-stage ripple counter (IC4)
- 1 BC640 PNP transistor (Q1)
- 2 BC559 PNP transistors (Q2, Q3)
- 1 BC639 NPN transistor (Q4)
- 1 BC547 NPN transistors (Q5)
- 5 1N4148 signal diodes (D1-D5)
- 1 15V Zener diode (ZD1)
- 1 5mm high-brightness red LED
- 1 5mm high-brightness green LED
- 1 5mm high-brightness blue LED

Capacitors

- 1 1000µF 10V electrolytic
- 1 220µF 16V low-ESR electrolytic
- 1 1µF monolithic ceramic
- 4 100nF MKT
- 2 4.7nF MKT
- 1 33pF ceramic
- 1 12pF ceramic

Resistors (0.25W 1%)

- 1 10MΩ
- 1 1MΩ
- 1 220kΩ
- 1 100kΩ
- 2 22kΩ
- 1 15kΩ
- 3 10kΩ
- 1 6.8kΩ
- 2 4.7kΩ
- 1 1.5kΩ
- 2 1kΩ

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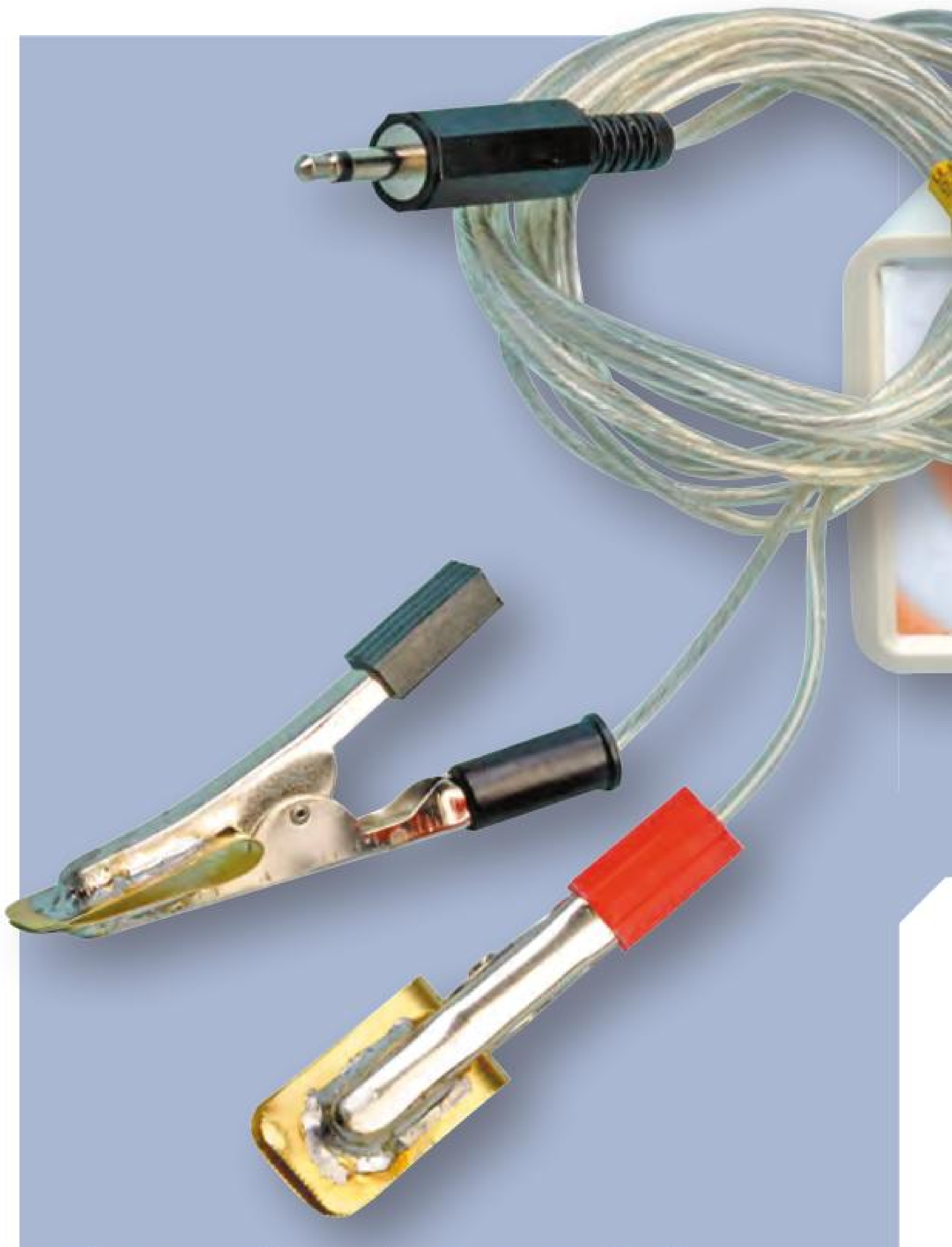


The ear electrodes are made by soldering U-shaped brass pieces to alligator clips (after the teeth have been filed off).

the PC board. That done, push the two leads through the board and solder the connector in place.

The LEDs go in next. Their leads must be bent down at right-angles 5mm from the lens, but first check the orientation. In each case, the longer lead goes through the hole marked 'A' (anode) on the overlay. Once the leads have been bent, insert each through a plastic mounting block and attach this to the PC board using double-sided tape. Once they are in place, solder and trim the leads.

Inductor L1 can go in next, then using a hacksaw, trim VR1's shaft to 9mm (as measured from the end of its mounting thread). File off any burrs before mounting it on the PC board.

Finally, attach the battery holder to the board using M2 machine screws and nuts. Alternatively, if these are not available, it can be held down using double-sided tape. Once it is firmly attached, solder its pins.

Making the electrodes

The electrodes are made from a 100 × 12mm piece of brass sheet and some alligator clips.

First, cut the brass sheet into two 50 × 12mm strips, then bend each strip into a 'U' shape using a thin piece of scrap wood fixed in a vice. That done, file the teeth off the alligator clip jaws and burnish the inner faces and edges with emery cloth. The U-shaped brass pieces can then be inserted into the jaws of the alligator clips and soldered in place (see photo).

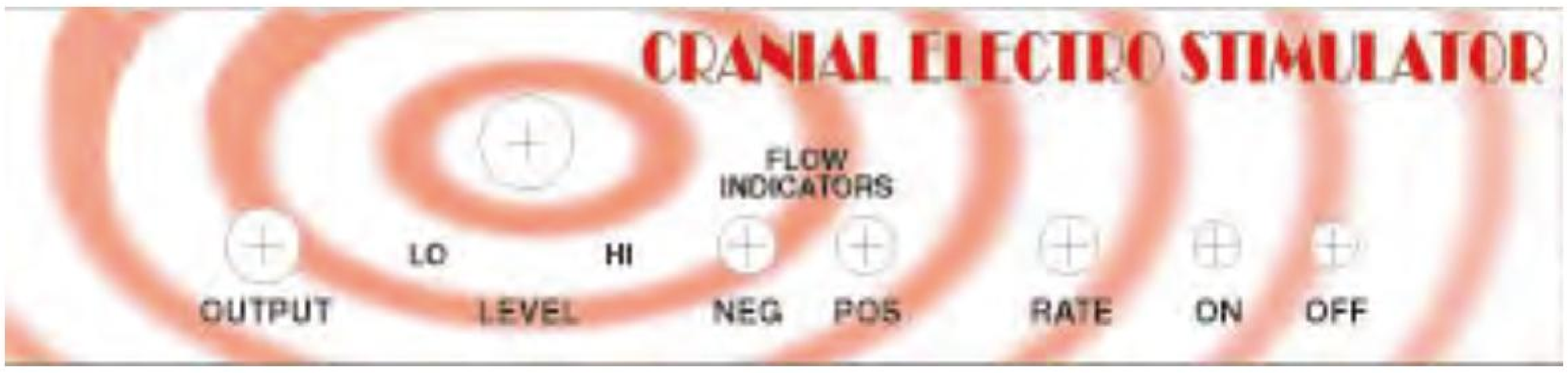
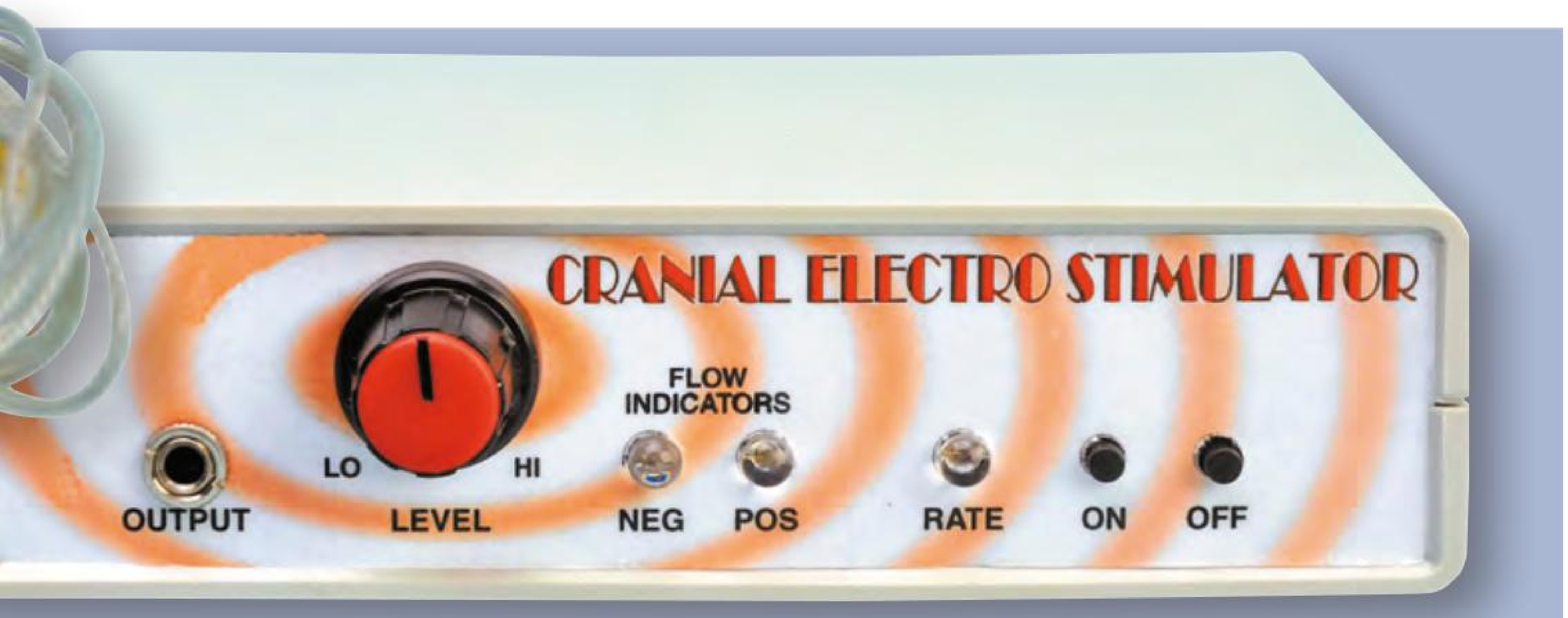
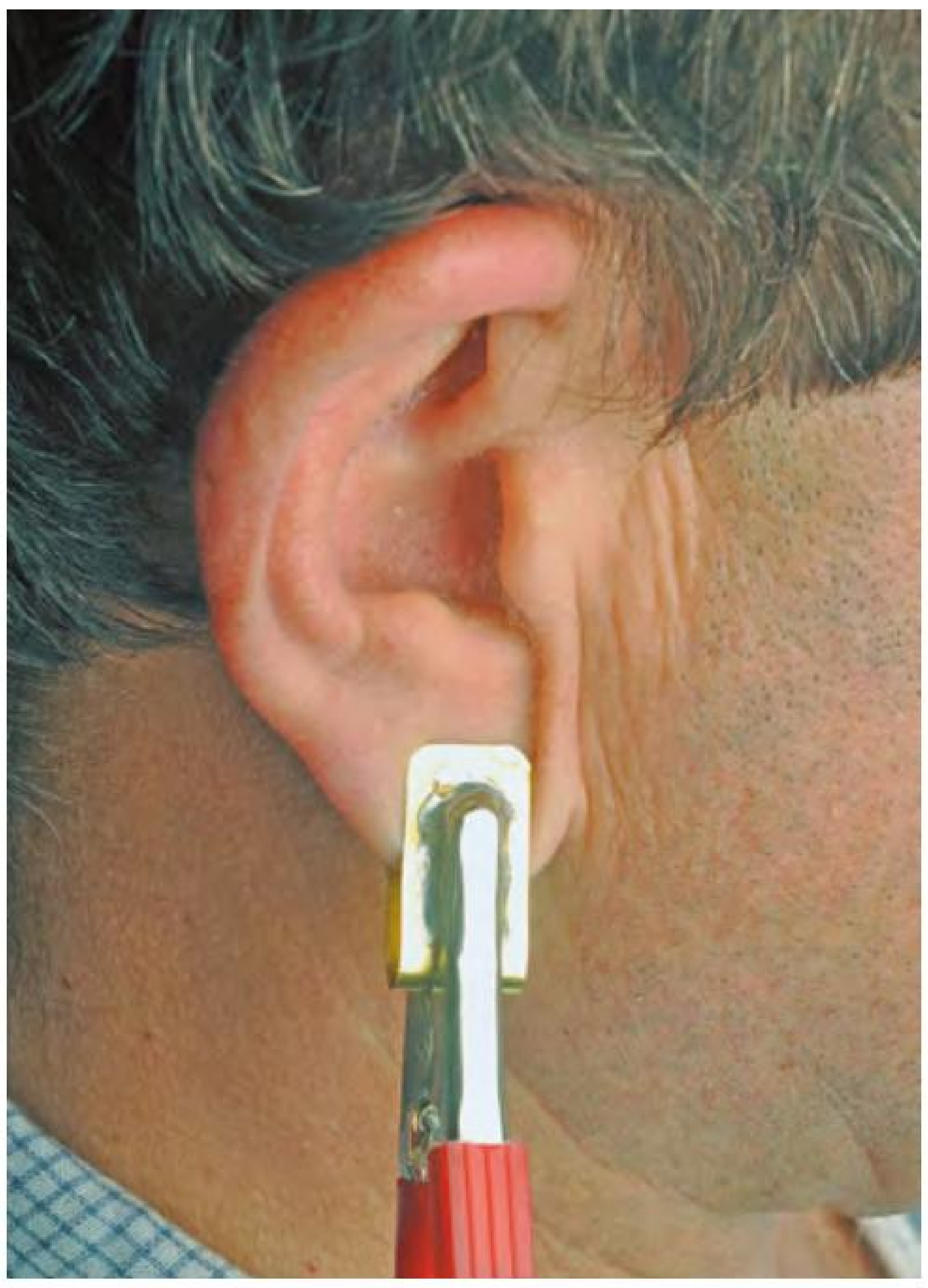


Fig.5: this full-size artwork can be copied and used as a drilling template for the front panel. It can also be downloaded in PDF format from the *EPE* website.



The electrodes plug into the output socket on the front panel. Also on the front panel are the on-off buttons, the current-flow indicator LEDs and the level control.



The U-shaped brass pieces ensure operator comfort when the electrodes are attached to the ear lobes

Next, trim and file away any excess at the edges, then use the emery cloth to remove any sharp jags. Make sure the clips have no sharp protrusions then test them on your earlobes. If they are too tight, the tension can be adjusted by bending the spring.

Once the clips are ready, solder them to one end of a 2m-long figure-8 cable, spreading it into a 'Y' shape about 30cm from the end. That done, slide heatshrink tubing over the split and shrink it down, to prevent the cable from pulling apart further. Solder the wires at the other end of the cable to the two tabs of a 3.5mm mono phono jack plug.

Alternatively, rather than making your own electrodes, you may be able to make use of ECG or TENS electrodes, which can be bought from some pharmacies.

Testing the board

If you have a bench supply, set it to 6V with a current limit of approximately 20mA. Otherwise, use the four cells to power it for testing.

If possible, it is a good idea to insert a DMM in series with the supply to check the current flow. Initially, leave the ICs out of their sockets (assuming they are not soldered to the board). Also check that the board is resting on a non-conductive surface.

When the supply is connected, the current should be practically zero. If so, switch off and insert the ICs, then switch it back on. With the ICs in place, the current drain should be around 0.03µA. However, this is below the measurement range of most DMMs so they will read zero. If the current is significantly above the expected level, disconnect the supply and check for assembly errors.

Now press the 'ON' button and watch the current reading. It should increase to around 8-10mA and the RATE LED should flash. When the RATE LED is on, the current reading will be slightly higher. Use a voltmeter to check the voltage between pins 16 and 8 of IC2 – it should be around 15V.

If that checks out, turn VR1 fully anti-clockwise, plug in the electrodes and install the shorting block on LK1. Now temporarily connect the electrodes together (ie, create a short circuit) and slowly turn VR1 clockwise. LED2 and LED3 should now begin to flash alternately at 1Hz, getting brighter as VR1 is turned up.

Finishing up

Assuming it all works correctly, the board can now be installed in the case.

First, use Fig.5 as a drilling template for the front panel. Start each hole using a pilot drill, then enlarge it to the correct size using larger drill bits or a tapered reamer, to ensure they stay round. Once the holes are made, check that they line up properly with the PC board.

The front-panel label can now be prepared. You can either copy Fig.5 or download a front panel label in PDF format from the *EPE* website. Once it is printed, laminate it and cut out the necessary holes, then attach it to the front panel using a thin smear of silicone sealant or spray adhesive.

Leave the sealant to cure overnight before attaching the PC board assembly. It's just a matter of feeding the board components through their corresponding front panel holes, then securing the panel by fitting the nuts to the output socket and potentiometer. The knob can then be fitted to the pot shaft.

Before the board can be lowered into the case, two plastic standoffs at the front of the case (towards the centre) must be removed. These can be filed away or cut off with large side-cutters. The board assembly can then be lowered into the case and secured in place using four self-tapping screws.

Finally, install the jumper link on LK1-4, depending upon the repetition rate you want to use, and attach the lid. If you are not sure, start with 0.5Hz; you can always remove the lid later to try the other settings.

Using it

Before using it, turn VR1 fully anti-clockwise. Attach the electrodes to the recipient (or yourself) and press the ON button. The RATE LED will flash at 1Hz to confirm that the device is operating.

Now slowly turn up VR1. When the green and blue LEDs barely light, this indicates that around 25µA is flowing through the electrodes (and thus the recipient). At full power, around 500µA can flow and the LEDs will light brightly. As previously stated, the two LEDs indicate the current flow in each direction.

We recommend the use of alkaline cells for this project, as they last well in devices which draw a small amount of current over a long period and also have a good shelf life.

That's it. We hope that you find this project sufficiently stimulating (groan!).

'A Lump In The Coax'

"Lumpincoax"
Mini Audio Mixer
SILICON CHIP
Hylex

Mini Audio Mixer

We've published a number of audio mixers, large and small, over the years but they've all been 'general purpose'. Not that that's a bad idea – it's just that when you need one for a specific purpose, you need a specific purpose mixer!

Design by Nicholas Vinen
Words by Ross Tester and Nicholas Vinen

In another life, I do a lot of commentary and announcing at surf lifesaving carnivals and also do my share of MC-ing at other venues. But I have come across a problem many, many times and just as often longed for a solution to that problem. This is it!

So what's the problem?

I'm sure that anyone working in small clubs or similar venues has had this dilemma. Many clubs – as do many other community centres, halls, schools and so on – have a reasonable (and sometimes excellent) public address system installed.

Surf lifesavers use it to warn swimmers of dangers, they use it to provide information to the beach-going public and from time to time it's there for commentary when the club runs a carnival, or a school runs a fete.

The problem is that surf clubs and schools, like the vast majority of 'public' halls and sports venues, suffer badly from knob-twiddlers and system stuff-upperers: presumably well-meaning people who think they know what they are doing, invariably putting the PA system into shock (if not cardiac arrest!). You know what they say, 'a little knowledge is a dangerous thing ...'.

For example, the hirers who want 'more sound' and add in a couple of 'real good' speakers from their home hi-fi. Except they don't know that most PA systems are wired with 100V speaker lines. Others simply 'make adjustments', which end up being maladjustments!

Lock the PA away!

An increasing number of venues which I visit have their PA system firmly locked away in a cupboard so that no-one except the person responsible for the system can get at it. And, of course, that person is never around when needed.

The PA often simply has an accessible on/off switch, while all controls are pre-set to 'typical' levels, so that it really is simple enough for any idiot to use. 'Idiot' being the operative word in many cases.

Even if it isn't locked up, getting to the business end of the system to plug anything else in – an MP3 player, for example – is often near (or totally) impossible.

(I'm sure that manufacturers put all inputs and outputs on the back of amplifiers not just to tidy up the wiring but to cause the most frustration!)

Such systems invariably have either an XLR socket mounted on the locked box or a coax cable emerging from it, to which is attached a wired microphone (invariably on a too-short lead) – and that's it.

Many have given up on wireless microphones, usually because the mic itself keeps on disappearing and/or they've suddenly found their wireless microphone is suffering from all sorts of strange interference.

So you get to a venue and find all you have to work with is a wired microphone which doesn't even reach the outside, so you can't actually see what's happening (I always carry a long XLRF-XLRM 'extension' mic lead with me these days!).

But that's it: if you need to add music, all you can do is do it acoustically (eg, the MP3 player's speaker to microphone) which invariably sounds awful.

If you want to use a wireless microphone (for ceremonies, interviews, etc) away from the system – tough luck! And if there are two or more announcers, you're continually swapping the fixed mic back and forward.

It's all pretty unsatisfactory – and unless you've been in the situation, you probably won't appreciate just how frustrating it all is.

Which started us thinking . . .

While it's not something every reader would need to worry about (indeed, very few will ever have the problem) we thought, 'why not come up with a mini mixer specifically designed for this purpose'.

Then we reasoned that such a mixer would be popular with a lot of others who have PA systems – schools, for example – and wanted to be able to lock it away so that the twiddlers couldn't . . . twiddle.

If at any time they wanted extra inputs, here would be the ideal way to do it. We mention schools here mainly because so many electronics-savvy teachers have told us that non-savvy 'expert' colleagues are the bane of their lives!

And we also thought of all those venues that have microphone sockets (XLRs) spread around the building wired back to the PA amp, somewhere, so that mics could be plugged in and used anywhere. With this *Mini Mixer*, such installations would be so much more versatile and usable.

Specifications: (22Hz-22kHz bandwidth, unweighted, 50mV RMS in/out unless otherwise stated)

Signal-to-noise ratio: >65dB
Total harmonic distortion plus noise: 0.06% (1kHz)
Common-mode rejection ratio: >40dB (typically 55dB)
Frequency response: 50Hz-35kHz (–3dB)
Gain: ~1 for microphone input, 0-0.25 for other inputs
Signal handling (microphone input): at least 1V RMS
Signal handling (other inputs): 0.2-2.5V RMS for 50mV output
Supply current: 0.5mA (typical)
Battery: CR2032 (3V Lithium), 3.7V Li-Po or 9V alkaline/dry cell
Battery life: 200+ hours with CR2032, 2000+ hours with Li-Po
Operating voltage: minimum 2.1V, nominal 2.7-4.2V
Li-Po charger input: 5V DC @ up to 500mA

Our ideas

A typical PA system uses either a dynamic or electret microphone (the latter are less usual as they tend to be more easily damaged). These mics usually have an output in the region of 10-50mV and any microphone worth its name uses XLR connectors – there's a male XLR socket built into the microphone, the coax mic lead has a female plug to match and a male plug back at the amplifier to match the female input socket.

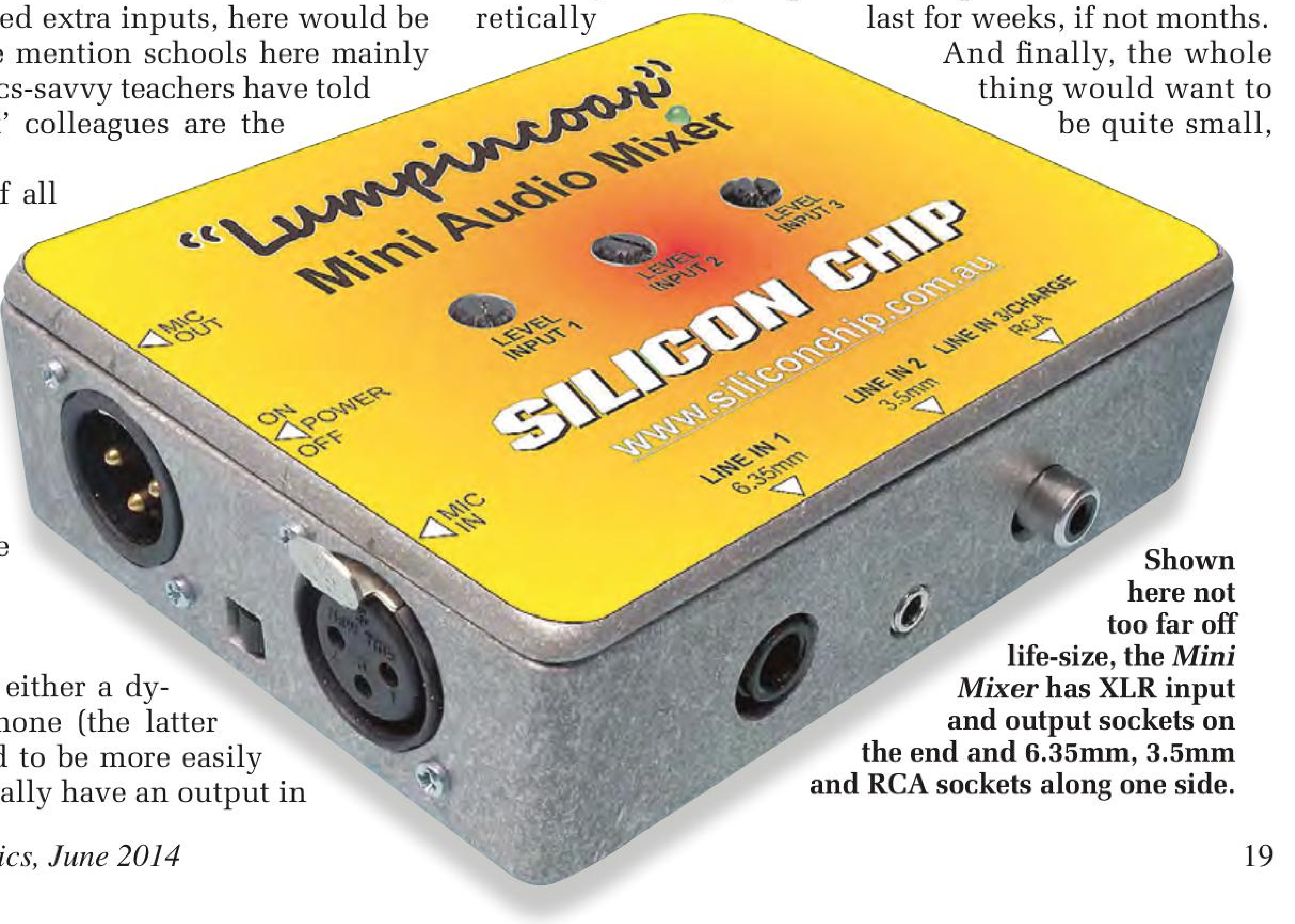
What if we were to come up with a mixer which simply inserted between the mic lead and the microphone and effectively gave a 'straight through' connection for that microphone – in other words, act as if it wasn't there? That way there would be no difference in the normal operation of the PA.

It could almost be regarded as a 'lump in the coax'. But that same mixer could also accept a couple of other inputs – say from an MP3 or CD player for music and from a wireless microphone receiver. The beauty of both of these is that they would be expected to be much the same output level – perhaps 1V, maybe less – which would make the mixer inputs virtually universal.

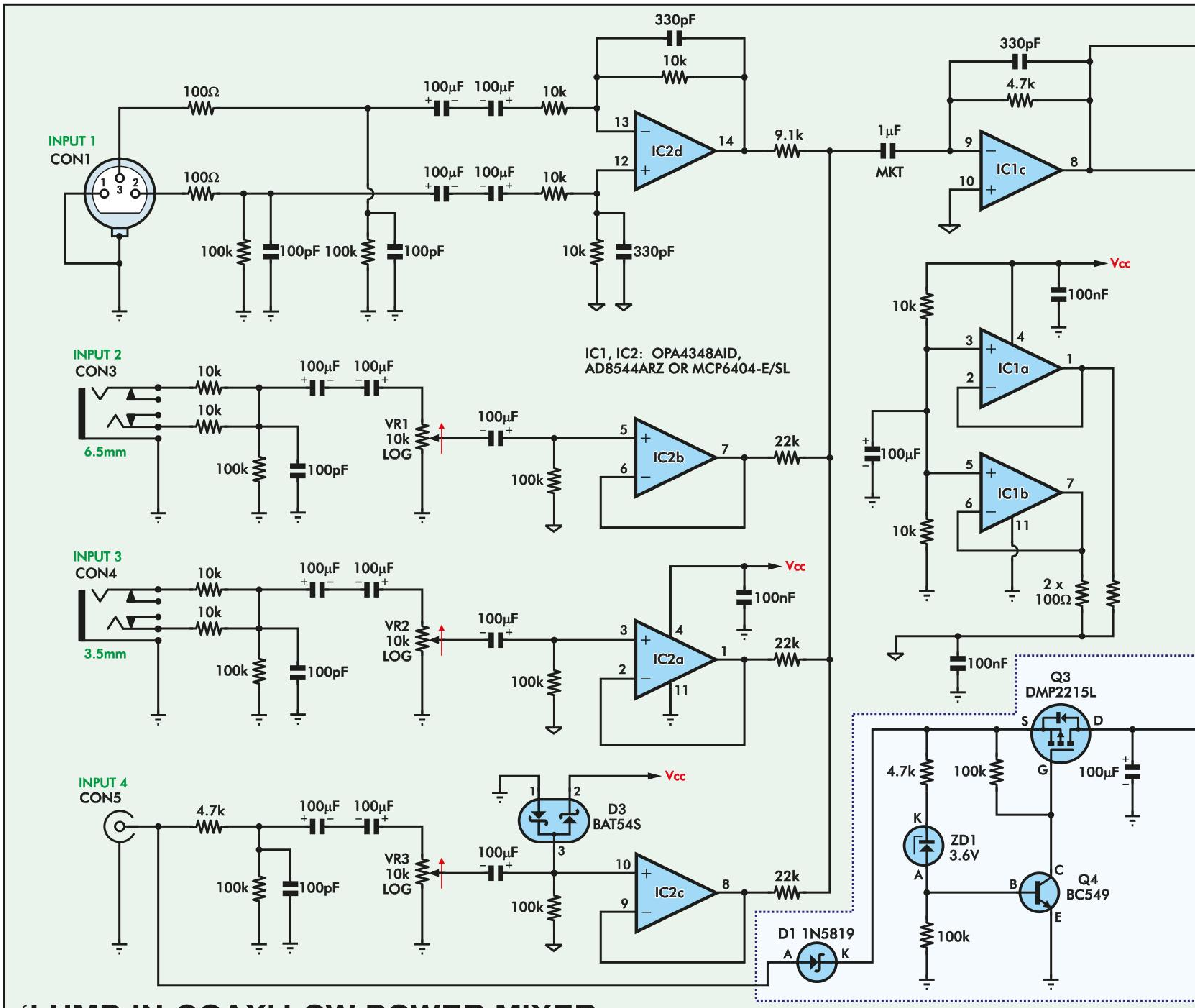
We would want to make the mixer battery-operated for convenience, so we would need a very low power op amp if we wanted the battery to last any length of time. Speaking of batteries, a 3.7V Lithium-Ion (or even $LiFePO_4$) would be eminently suitable, given the right design.

With very low drain, even a button cell could be used – or we could use a mobile phone battery which are very flat and give a very respectable output – that would theoretically last for weeks, if not months.

And finally, the whole thing would want to be quite small,



Shown here not too far off life-size, the *Mini Mixer* has XLR input and output sockets on the end and 6.35mm, 3.5mm and RCA sockets along one side.


INPUT 1
CON1
100Ω
100Ω
100k
100pF
100k
100pF
100µF
100µF
10k
330pF
10k
13
12
IC2d
14
9.1k
1µF
MKT
330pF
4.7k
9
10
IC1c
8
10k
330pF
Vcc
100nF
10k
3
4
IC1a
1
2
100µF
5
IC1b
7
6
11
10k
2 x 100Ω
100nF
IC1, IC2: OPA4348AID, AD8544ARZ OR MCP6404-E/SL
INPUT 2
CON3
6.5mm
10k
10k
100k
100pF
VR1 10k LOG
IC2b
22k
INPUT 3
CON4
3.5mm
VR2 10k LOG
IC2a
22k
Q3 DMP2215L
S
D
G
4.7k
100k
100µF
K
ZD1 3.6V
A
C
B
Q4 BC549
E
100k
INPUT 4
CON5
4.7k
D3 BAT54S
VR3 10k LOG
IC2c
22k
D1 1N5819
A
K

‘LUMP-IN-COAX’ LOW POWER MIXER

Fig.1: the circuit is quite conventional for an audio mixer, albeit with a few clever refinements (eg low-voltage op amps) for operating at very low power. Input 4 doubles as a charging connection for Li-Po battery, if fitted. The back-to-back (series) 100µF capacitors are used because two of these are significantly cheaper than one non-polarised 50µF capacitor.

with a minimum of controls to make it as foolproof as possible. Let’s not worry about tone controls or other ‘niceties’.

Our design

We’ve come up with a mini-mixer that fits all the criteria above (and then some!). In fact, it has some rather snazzy features and offers performance that is nothing to be sneered at!

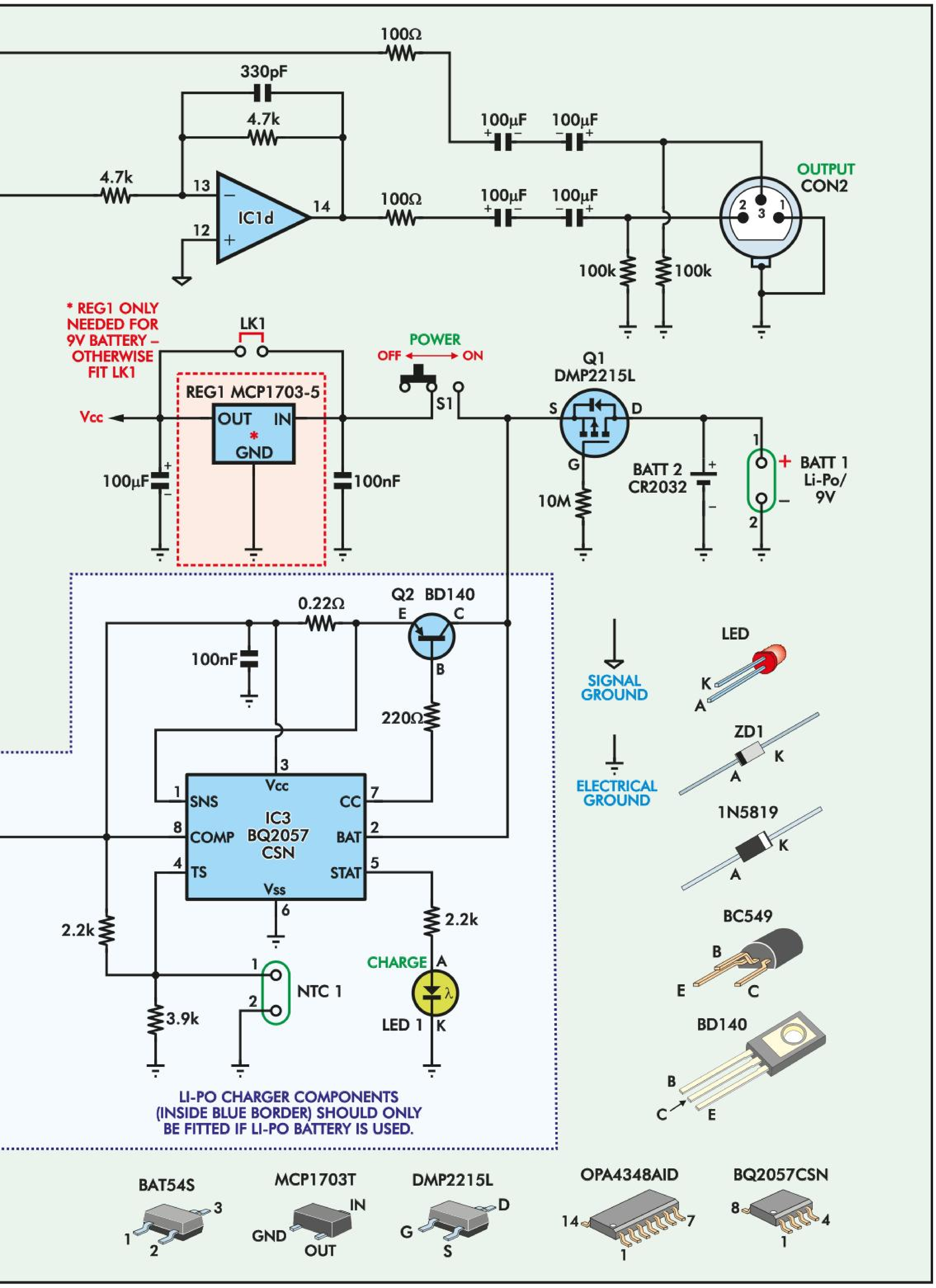
It’s small (built into a 120mm × 93.5mm × 35mm diecast box). It has minimal controls – just a ‘preset’-type gain control for each of the three inputs and these don’t even have knobs (again to discourage the twiddlers).

We used mini pots with ‘screwdriver slots’ on the end – they emerge just far enough from the front panel to fit a fingernail! (OK, use a small flat-bladed screwdriver if you must!).

There are five sockets: an XLR female and male on the end to accept the microphone lead and the lead to the amplifier, a 6.35mm ‘phono’ socket, a 3.5mm mini phono socket and an RCA socket. The larger phono sockets are often used on wireless microphones, while the 3.5mm mini sockets are very commonly used on MP3 and other small music players, radios, etc, normally as headphone sockets.

But we’ve been particularly clever with the RCA socket: feed it with audio signal, it acts as you would expect. But if you feed it with 5V DC (eg, from a USB socket or plugpack), it also serves as the charging point for the internal battery; more on this shortly.

The only other control is the power switch, necessary if you use the onboard CR2032 lithium battery, but almost redundant if you use a larger phone battery, as mentioned earlier.


100Ω
330pF
4.7k
4.7k
13
12
14
IC1d
100Ω
100µF
100µF
100µF
100µF
100k
100k
OUTPUT
CON2
2
1
3
* REG1 ONLY NEEDED FOR 9V BATTERY – OTHERWISE FIT LK1
LK1
POWER
OFF
ON
S1
Q1
DMP2215L
S
D
G
10M
REG1 MCP1703-5
OUT
IN
GND
Vcc
100µF
100nF
BATT 2
CR2032
BATT 1
Li-Po/
9V
Q2 BD140
0.22Ω
E
C
B
100nF
220Ω
SIGNAL GROUND
ELECTRICAL GROUND
LED
K
A
ZD1
1N5819
BC549
BD140
IC3
BQ2057
CSN
SNS
COMP
TS
Vcc
CC
BAT
STAT
Vss
2.2k
2.2k
3.9k
NTC 1
CHARGE
LED 1
LI-PO CHARGER COMPONENTS (INSIDE BLUE BORDER) SHOULD ONLY BE FITTED IF LI-PO BATTERY IS USED.
BAT54S
MCP1703T
DMP2215L
OPA4348AID
BQ2057CSN

One point to note: a lot of mobile phones use headphones fitted with 2.5mm ultra-mini plugs. We haven't allowed for a 2.5mm socket but 2.5 to 3.5mm adaptors are very common and very cheap.

Finally, it's designed to suit dynamic microphones only and then only those that use XLR plugs. No provision has been made for electret phantom power.

Circuit description

The balanced microphone signal from CON1 is converted to an unbalanced signal, which is then mixed with the signals from the other three inputs. The result is then again converted to a balanced signal at output CON2. For all intents and purposes, the amplifier won't even know it's there!

The gain of the balanced-unbalanced-balanced path is close to unity, while the gain for the other three channels can be varied from one quarter down to zero.

Inputs CON3 (6.5mm jack socket) and CON4 (3.5mm jack socket) can accept either mono or stereo plugs; if a stereo signal is applied, it is mixed down to mono. CON5 (RCA socket) is mono only.

Potentiometers VR1-VR3 are used to adjust the level of these signals respectively and in each case, the result is then buffered by an op amp and then fed to the mixing node.

Why no volume control for the microphone input? The microphone volume is adjusted via the PA amplifier, so we just need three pots to set the relative level for the other inputs. Now let's look at the circuit's operation in a little more detail.

Balanced input

The balanced microphone delivers identical but opposite polarity (out-of-phase) signals to op amp IC2d which is configured for balanced inputs but has an unbalanced (ie, single-ended) output at pin 14. Both signals pass through identical RF filters comprising 100Ω series resistors and 100pF ceramic capacitors, while two 100kΩ resistors provide a DC bias to 0V.

Following the RF filters, both signals are AC-coupled through back-to-back 100µF capacitors to the inputs of IC2d.

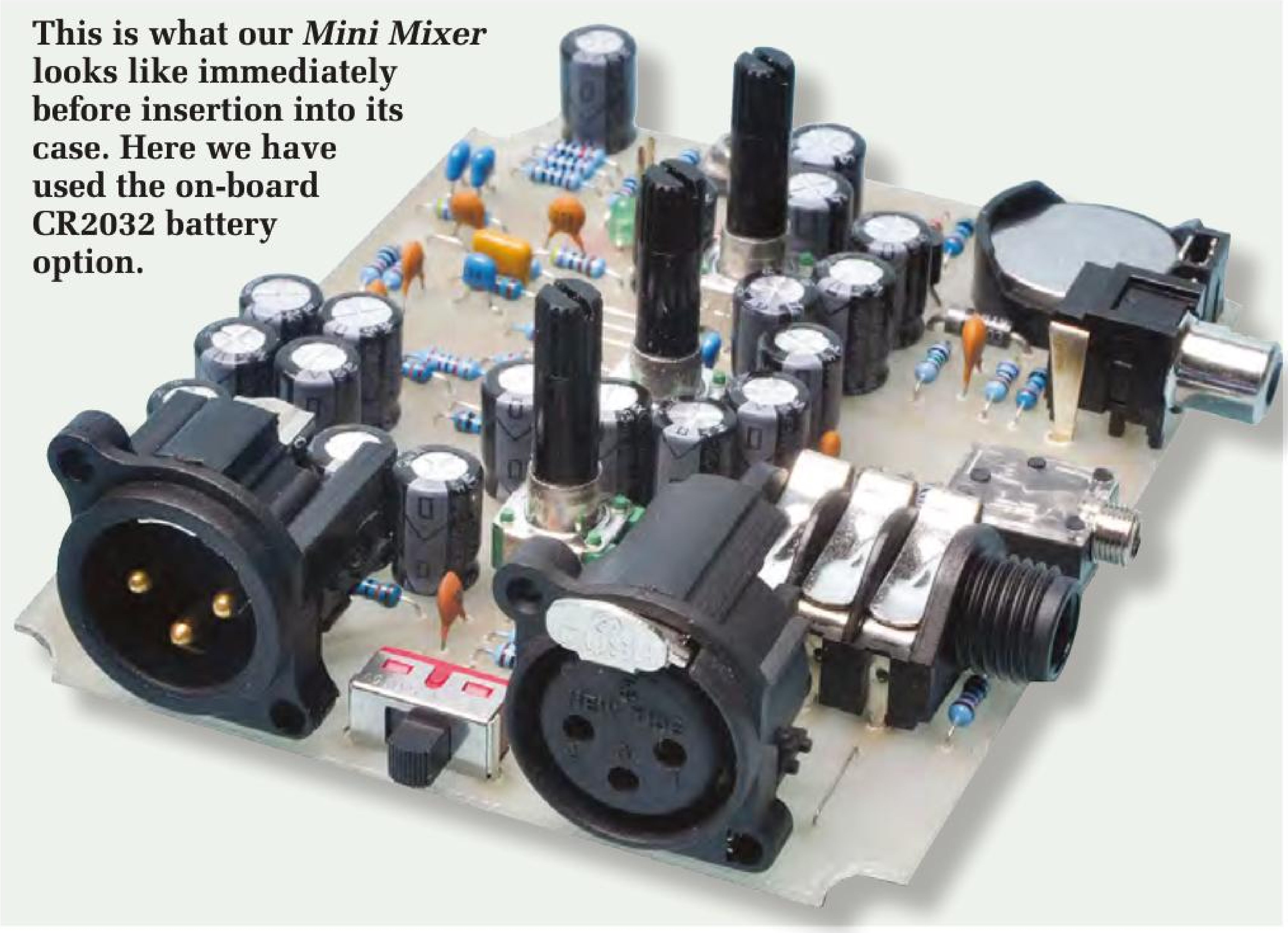
Note that the signal ground for IC2d (and indeed, all the op amps) has a different symbol than power supply ground and is actually at half-supply, ie, about 1.5-2V.

We have used back-to-back electrolytics here because PA gear can be connected to other equipment that might have phantom power, might be faulty, etc. So all inputs and outputs tolerate ±48V DC without damage.

Standard electros though are usually cheaper and smaller than non-polarised types; two 100µF 50V capacitors connected in this manner are equivalent to a 50µF 50V non-polarised capacitor.

IC2d converts the balanced signal from the microphone to unbalanced while largely rejecting unwanted signals picked up in the cable (eg, hum and noise). The output of IC2d is the signal from pin 2 of CON1 minus the signal at pin 3. So extraneous signals picked up equally by both lines in the microphone cable will be cancelled out or at least heavily attenuated.

The two 330pF capacitors roll off the frequency response of this amplifier, forming a low-pass filter with a –3dB point at around 48kHz, rejecting any signal which may be picked up that is above regular audio frequencies but low enough to pass through the RF filters.



This is what our *Mini Mixer* looks like immediately before insertion into its case. Here we have used the on-board CR2032 battery option.

Other inputs

The circuits for unbalanced inputs 2 and 3 (CON3 and CON4) are identical. Two 10kΩ resistors down-mix the stereo to mono; if a mono jack plug is inserted, these are effectively paralleled to form a single 5kΩ resistor. A 100pF capacitor in combination with this forms the RF filter and a 100kΩ resistor provides a DC path to ground.

The signal is then AC-coupled to volume control pot VR1 (or VR2). The output from its wiper is AC-coupled again to ensure that no DC flows through VR1, which would cause noise when the pot is turned. A 100kΩ resistor sets the DC bias to half-supply and the signal is then buffered by voltage follower IC2b (or IC2a) before being applied to the mixer stage.

The signal path from the mono RCA connector (CON5) is the same as above, but being mono, a single 4.7kΩ series resistor is used rather than a pair of 10kΩ resistors. Also, CON5 can be used to charge the onboard Li-Po battery, as we shall explain later. In this case, dual Schottky diode D3 prevents current flowing into op amp IC2c as the coupling capacitors charge when DC is applied to CON5.

The mixer

The four signals are fed to a virtual earth mixer based around inverting amplifier IC1c, which has a 4.7kΩ feedback resistor from its output (pin 8) to inverting input (pin 9). Again, there is a 330pF roll-off capacitor for further attenuation of any signals above the audio band.

The output of IC2d is applied to the mixing node via a 9.1kΩ resistor and 680nF AC-coupling capacitor. This capacitor forms a high-pass filter with IC1c's feedback resistor to remove low bass, giving a –3dB point around 50Hz. This is primarily to deal with microphone thump, but it also attenuates by about 3dB any 50Hz hum which may be picked up.

The other three inputs are applied to the mixing node via 22kΩ resistors, giving them a gain of about 0.21 (4.7kΩ÷22kΩ). The signals from these inputs will generally be at or around line level, ie, in the range of 0.5-2V RMS, while the microphone signals will be much lower at around 50mV. So this attenuation gives VR1-VR3 a more useful adjustment range.

Note also that the gain in this stage for the microphone input is 4.7kΩ÷9.1kΩ = 0.52. The following unbalanced-to-balanced converter has a gain of two, so these cancel out.

The mixed signal from the output of IC1d is applied to pin 3 of output CON2 via a 100Ω current-limiting resistor and another pair of AC-coupling capacitors with a 100kΩ DC bias resistor to ground. The mixer stage (IC1c) is inverting, so its output goes to the inverted signal pin (pin3) of the balanced (XLR) connector, CON2.

For the non-inverted output (pin 2 of CON2), the signal from IC1c is inverted again, without gain, by IC1d, which gives it the same polarity as the input signal.

Virtual earth

The two remaining op amp stages out of the eight (IC1a and IC1b) are used to create and buffer the half supply virtual earth. This is generated by a pair of 10kΩ resistors connected across the supply and filtered with a 100µF capacitor, so that it is effectively grounded for AC signals.

Voltage followers IC1a and IC1b drive the virtual earth rail through 100Ω resistors with a 100nF capacitor to ground. The capacitor reduces the impedance of this rail at high frequencies, where the impedance of the op amp outputs could be quite high, while the 100Ω resistors isolate this capacitance from the op amps to avoid oscillation.

Li-Po charger

There are three basic options for the power supply: an on-board CR2032 Lithium button cell, a 9V battery or 3.7-4.2V rechargeable lithium polymer (Li-Po) cell. The latter option offers the longest battery life, potentially thousands of hours, with the bonus that you don't have to open up the case to change the battery if it goes flat.

Instead, you simply apply 5V DC to the central pin of CON5 (the RCA connector) and an internal charging circuit brings the cell back up to full charge. Charge current starts at around 500mA and drops off as the cell approaches full charge. For a typical 1000mAh cell, a full charge takes up to two hours. So for a two-hour charge you could get up to 2,000 hours operation!

When 5V DC is applied to CON5, schottky diode D1 becomes forward biased and current flows through 3.6V Zener diode ZD1 and turns on NPN transistor Q4. Q4 in turn pulls the gate of P-channel MOSFET Q3 low, allowing the power to flow through D1 and Q3 into the 100µF supply bypass capacitor for the battery charger circuit.

This isolates the charger circuit from any signal applied to CON5 during normal operation, up to at least 2V RMS (2.8V peak). When Q4 is off (ie, no charging voltage is applied), Q3's gate is pulled to its source voltage by a 100kΩ resistor, keeping it switched off. Similarly, a 100kΩ resistor ensures that a small amount of leakage current through ZD1 will not turn on Q4.

IC3 (BQ2057C) is a dedicated lithium ion/lithium polymer charging IC. There are four versions of this

IC, to suit one and two cell batteries with 4.1V or 4.2V charge termination voltages, depending on the cell chemistry. Most modern Li-Po cells can be charged safely to 4.2V so that is the version we have used (see panel for details).

Li-Po cells need a constant current/constant voltage charge cycle with accurate termination to give a good life and that's all handled by IC3. It controls PNP power transistor Q2 to regulate the current and voltage to the cell, with current sensed by the voltage drop across the 0.22Ω shunt resistor. IC3 turns LED1 on only while the cell is charging – the LED does not waste power in normal operation.

IC3 has provision for an NTC thermistor, which can be attached to the cell to monitor its temperature so it can stop charging if it gets too high. This is optional; if you want to fit an NTC thermistor, it should be a nominally 10kΩ type and wired across the NTC1 terminal. Otherwise, connect a 10kΩ resistor across this terminal.

Note that all the charging circuitry from D1 through to Q2 may be omitted if you *are not* planning to use a Li-Po battery to power the unit.

Power supply

The Li-Po battery is charged via P-channel MOSFET Q1, which prevents damage in case the cell is connected backwards. With the cell in the correct orientation, Q1's gate is pulled to ground while its source goes high (bootstrapped by its body diode) and thus it switches on, allowing power to flow from the cell to the circuit and also allowing charge current to flow into the cell from Q2.

Otherwise, Q1's gate is pulled high and being a P-channel type, it remains switched off. In this state, its body diode is also reverse-biased so no current can flow.

Slide switch S1 controls power to the mixer, but the unit can still be charged while off because the charging current does not flow through S1.

REG1 is only needed if you want to run the circuit off a 9V battery, as IC1 and IC2 have a maximum operating voltage of 5.5V. The MCP1703-5 has a very low quiescent current so that it doesn't spoil the mixer's low current drain. If using a lithium or Li-Po cell, omit REG1 and fit LK1 instead (but you should fit the two bypass capacitors anyway).

Parts list – 'Lump in The Coax' Mini Mixer

1 diecast aluminium enclosure, 120 × 93.5 × 35mm
1 PCB, available from the *EPE PCB Service,* coded 01106131, 110mm × 85mm
1 PCB-mount right-angle female compact XLR socket (CON1)
1 PCB-mount right-angle male compact XLR socket (CON2)
1 PCB-mount switched 6.35mm stereo jack socket (CON3)
1 PCB-mount switched 3.5mm stereo jack socket (CON4)
1 PCB-mount switched RCA socket (CON5)
1 right-angle SPDT slide switch
2 2-way pin headers, 2.54mm pitch (BAT1, NTC1)
4 No.4 × 9mm self-tapping screws or M2.5 machine screws
1 M3 × 6mm machine screw and nut
1 200mm length 0.7mm diameter tinned copper wire
1 110 × 85mm sheet of insulating material (eg, PET)
1 lid label

Semiconductors
1 DMP2215L P-channel SMD MOSFET (Q1)
2 OPA4348AID* quad rail-to-rail micropower op amps (IC1, IC2) (element14 1706654)
* AD8544ARZ and MCP6404-E/SL are also suitable but with higher minimum operating voltage.

Capacitors
20 100µF 50V (25V may be used with less margin)
1 1µF MKT/polyester (code 1U, 1.0 or 105)
5 100nF monolithic multi-layer [MMC] (code 100n, 0.1 or 104)
4 330pF disc ceramic (code 330p or 331)
5 100pF disc ceramic (code 100p or 101)

Resistors (0.25W, 1% unless otherwise stated)
1 10MΩ
12 100kΩ
3 22kΩ
11 10kΩ
1 8.2kΩ
5 4.7kΩ
1 3.9kΩ
2 2.2kΩ
1 220Ω
6 100Ω
1 0.22Ω SMD 6331 (metric), 2512 (imperial)
3 10kΩ log vertical 9mm PCB-mount potentiometers

Parts needed for CR2032 button cell operation
1 PCB-mount 20mm button cell holder
1 CR2032 button cell

Parts needed for Li-Po cell operation
1 small 3.7V Li-Po cell with leads
2 2-way pin header plugs with crimp pins
1 BQ2057CSN Li-Ion/Li-Po charger (IC3) (element14 1652449)
1 BD140 PNP transistor (Q2)
1 DMP2215L P-channel SMD MOSFET (Q3)
1 BC549 NPN transistor (Q4)
1 1N5819 1A schottky diode (D1)
1 BAT54S dual series SMD schottky diode (D3) (element14 1467519)
1 3.6V Zener diode (ZD1)
1 3mm green LED (LED1)
1 10kΩ NTC thermistor, beta ~4000 (optional)
1 100mm length 4-way ribbon/rainbow cable
1 length double-sided, foam-cored adhesive tape
1 USB cable with type A connector at one end
1 RCA line plug

Extra parts for 9V battery operation (note: battery won't fit in specified case)
1 MCP1703-5 LDO micropower regulator, SOT-23 (REG1) (element14 1627178)
1 9V battery
1 9V battery snap with leads
1 2-way pin header plug with crimp pins
1 100mm length 4-way ribbon/rainbow cable

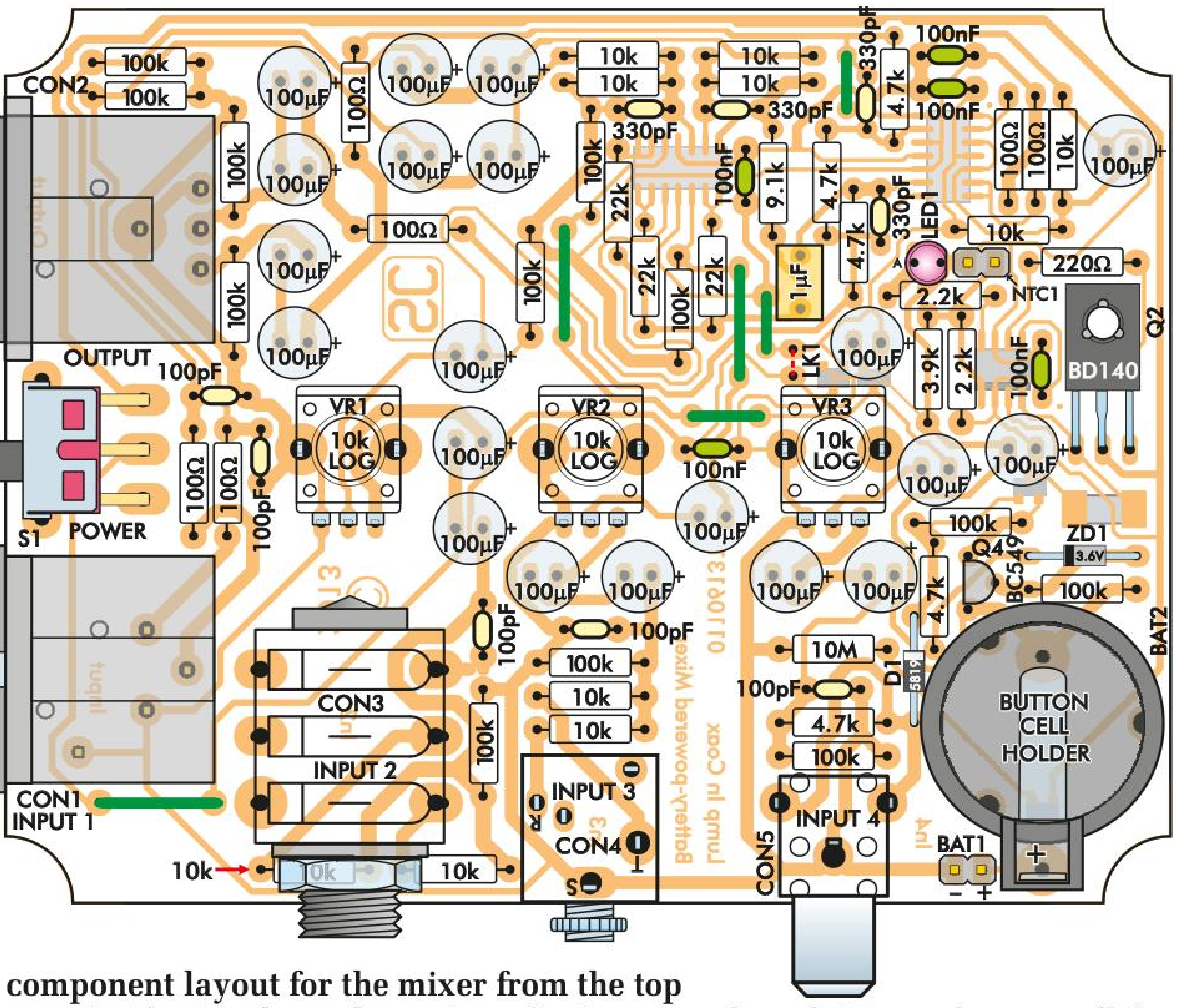


Fig.2: component layout for the mixer from the top (component) side. You have the option of using an on-board CR2032 button cell (as shown here), an external (rechargeable) Li-Po or even a garden-variety 9V type.

Performance and noise

The performance for this mixer is pretty good considering the low voltage and power consumption.

Lower-power op amps almost always have more noise and less bandwidth than their higher-power counterparts. That is because, to reduce their power consumption, the standing current in both the input pair and the voltage amplification stage (VAS) is reduced.

Dynamic microphones have quite a low output signal level – typically below 50mV RMS. That, in combination with the higher input noise of low-power op amps, limits the signal-to-noise ratio of the mixer. In practice though, 65dB is more than adequate for PA work.

If you aren't happy with that, there's an easy solution – swap the OPA4348 op amps with noise of 35nV/sqrt(Hz) for a lower-noise, pin compatible part such as the TL974 which has just 4nV/sqrt(Hz). We expect that will improve the signal-to-noise ratio by around 10dB.

But it does so at the cost of much increased battery current of 16mA and somewhat reduced signal handling capability as the TL974 does not have a rail-to-rail input. If you decide to swap the op amps, you will definitely want to use a Li-Po battery.

iPod compatibility

If you want to connect an iPod to the 3.5mm input socket, you can do so, but you may find that it's necessary to provide it with a lower value load resistance for it to operate correctly. This might apply to other MP3 players too, although most are happy driving a high load impedance. The solution is simple: replace the 4.7kΩ series resistor at this input with a 100Ω resistor and change the 100kΩ DC bias resistor to 1kΩ.

This may mean that the input can no longer be used with other signal sources, which is why we didn't do it that way in the first place.

Construction

The prototype mixer was built on a single-sided PCB, available from the *EPE PCB Service*, coded 01106131 and measuring 110mm × 85mm, but production boards will be double-sided, eliminating the need for wire links (shown in green in the diagram above).

Start by fitting the SMDs, beginning with op amps IC1 and IC2. Locate pin 1, which is normally indicated with a dot or stripe. If you can't find that, check for a bevelled edge on the PCB package, also on the pin 1 side. Put a little solder on one of the IC pads and while heating that solder, slide the IC in place.

When it's lined up with its pads, double-check that the IC is oriented correctly, then solder the rest of the pins. Then refresh the first one you soldered with a dab of extra solder. Remove any bridges with solder wick.

Carefully examine the solder joints with a powerful light and magnifying glass; a bad joint at this stage could cause problems later and it's quite easy to get solder on one of these pads without it actually adhering to the component pin (something we've had happen on more than one occasion). If necessary, add some heat and/or solder to any suspect joints.

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	10MΩ	brown black blue brown	brown black black green brown
☐	12	100kΩ	brown black yellow brown	brown black black orange brown
☐	3	22kΩ	red red orange brown	red red black red brown
☐	11	10kΩ	brown black orange brown	brown black black red brown
☐	1	8.2kΩ	grey red red brown	grey red black brown brown
☐	5	4.7kΩ	yellow violet red brown	yellow violet black brown brown
☐	1	3.9kΩ	orange white red brown	orange white black brown brown
☐	2	2.2kΩ	red red red brown	red red black brown brown
☐	1	220Ω	red red brown brown	red red black black brown
☐	6	100Ω	brown black brown brown	brown black black black brown

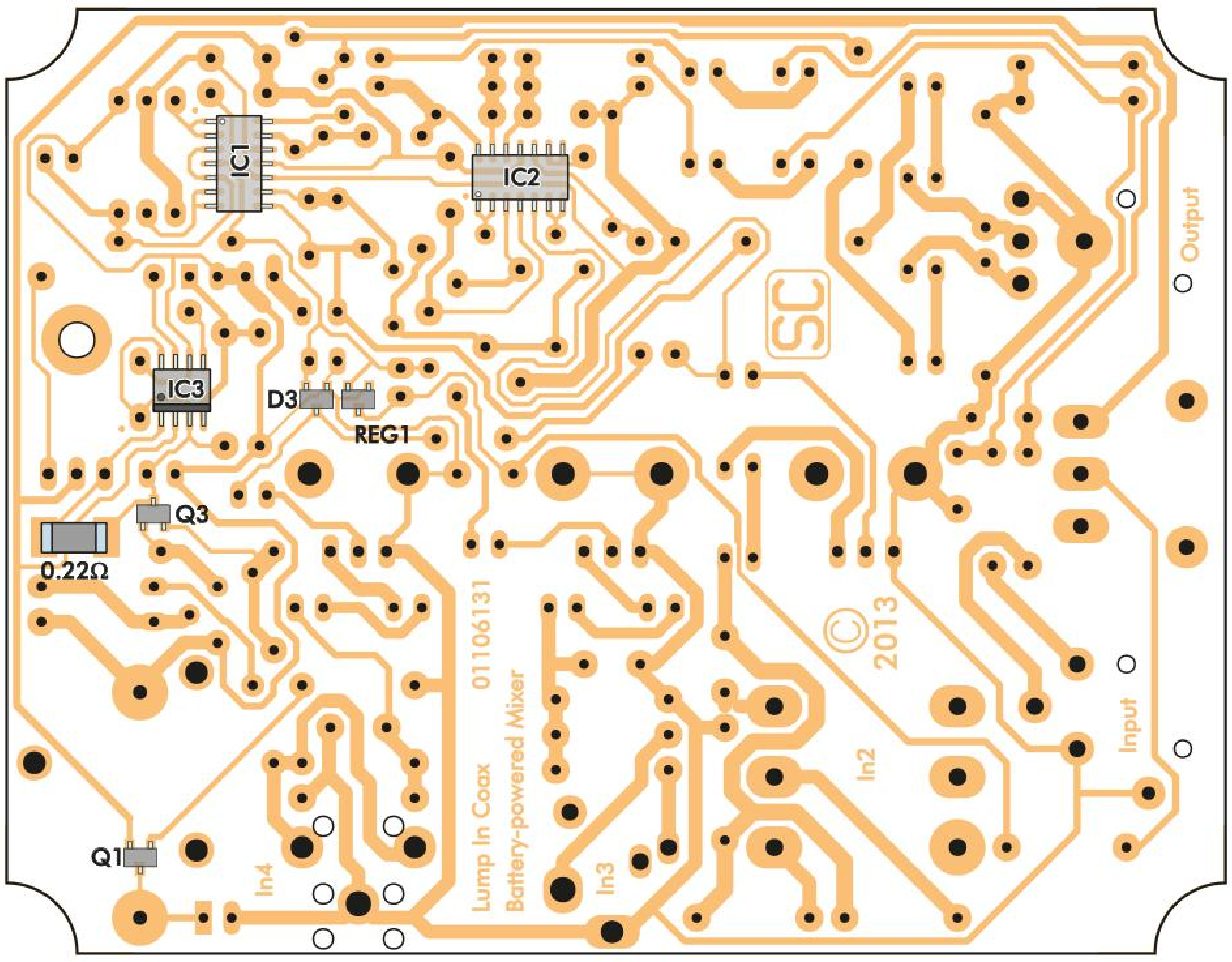


Fig.3: the underside (ie, normal copper side) of the PCB has seven SMD devices on it, as shown here and (partially) in the early prototype pic above right. These should be soldered in place before you start assembling the top side. While our prototype was a single-sided PCB, production boards will be double-sided.

Now fit MOSFET Q1 in the same manner. It's smaller but the pins are widely spaced. The leads should sit on the PCB surface; if they are sticking up in the air like a dead cockroach, the part is upside-down.

If you will be powering the unit from a 9V battery, fit REG1 in the same manner.

We believe that most constructors will want to use the lithium or Li-Po options; if you do use a 9V battery, you will have to fit the unit in a larger case than specified.

If you are using a Li-Po and want the on-board charging facility, install the associated SMD components now, ie, D3, Q3, IC3 and the 0.22Ω shunt resistor using the same basic technique outlined above.

Through-hole parts

If you ordered the board from *EPE* (or if it was supplied in a kit), it will already have the links as the top layer.

Otherwise (eg, if you etch your own single-sided board), fit the six wire links now (shown in green in Fig.2) using tinned copper wire, plus LK1 if you *aren't* using a 9V battery. Follow with the remaining resistors. Use the colour-code table as a guide, but also check their values with a DMM.

Diodes D1 and ZD1 go in next – but only if you are building the Li-Po version. In that case, you will also need to mount Q2 and Q4. For Q2, Bend its leads, feed them through the holes and then use the M3 screw to fasten its tab securely to the PCB before soldering the leads. The metal tab goes down, against the PCB (*not as shown in the photo*, which we changed).

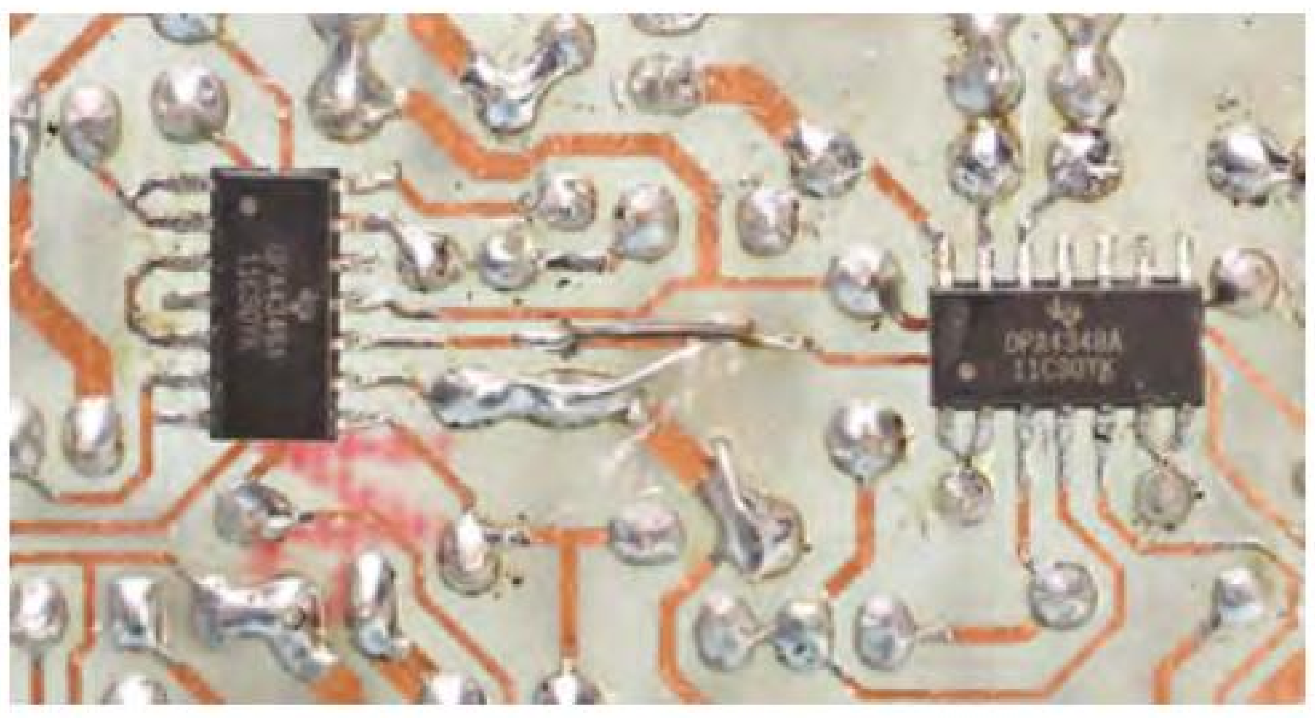
Next, fit all the ceramic capacitors (disc and monolithic multi-layer). Then solder in the 3.5mm jack socket, button cell holder (if required), slide switch S1 and the two 2-way pin headers.

Follow with the single MKT capacitor and then the electrolytics; these are all the same value and in the same orientation, with the positive (longer lead) to the right side of the board.

You can now mount the larger connectors, CON1-CON3 and CON5, as well as the three vertical pots. Push these down firmly into the mounting holes before soldering the two tabs and three pins. If building the Li-Po version, fit LED1 now, at full lead length, with its anode (longer lead) to the left. The PCB is now complete.

Connecting the Li-Po battery

We recycled a 3.7V 1500mAh 'Huawei' Li-Po battery from an unloved mobile phone (the battery still charged and held charge). We found (more by good luck than good management) that this 42 × 65 × 5mm battery fitted perfectly inside the case lid, alongside the pot shafts.



Even if you have to buy a new one, they're dirt cheap on ebay – for example, one the same as we used was £3 including postage from Hong Kong.

You can get Li-Po cells with leads attached, but if recycling an old one, like ours, identify which pads correspond to positive and negative and then solder a couple of appropriately-coloured wires to these (eg, from ribbon cable).

Connect a two-pin header to the other end of this cable by stripping the ends of the wire, crimping the two small pins to them (both to the uninsulated and insulated sections) and then pushing them into the plastic block. We like to solder the crimped joint too, but you have to be careful not to put much solder on or the pin may not go into the block.

For a 9V battery, you will need to attach a 2-pin plug to the wires from the 9V battery snap using the same method.

Charging cable

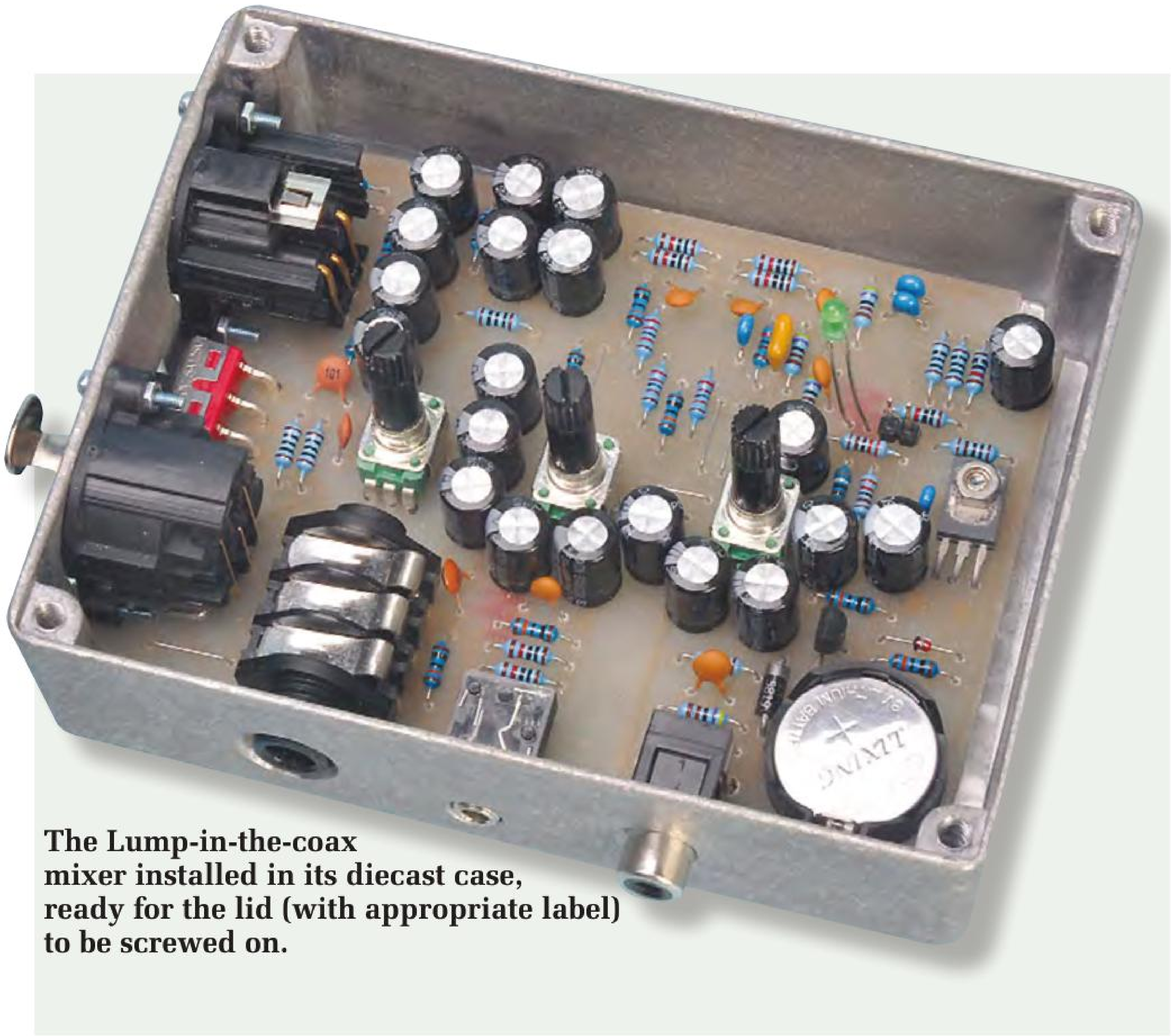
For the Li-Po version, you will also need to make a charging cable. You can charge from USB or a 5V DC plugpack or car adaptor.

To make a USB cable, take a cable with a Type A plug on one end and chop the other end off. Strip back some of the outer insulation, solder the white and green wires together and insulate them with small diameter heatshrink tubing.

Slide the rear of the RCA plug over the cable then solder the red wire to the centre pin and the black wire to the surround. Crimp the cable with the provided clamp and slide the rear cover back on. Plug it into a USB port and use a DMM to check that the centre pin is at +5V relative to the surround.

If charging from a plugpack, it's just a matter of fitting an RCA plug to the plugpack using a similar method.

If fitting an NTC thermistor to monitor the battery temperature, glue or otherwise attach it to the cell and run a couple of short leads back to another 2-pin plug as described above, to plug into the NTC1 header on the PCB. If



The Lump-in-the-coax mixer installed in its diecast case, ready for the lid (with appropriate label) to be screwed on.

you don't want to fit the NTC, solder or otherwise connect a 10kΩ resistor across the NTC1 header pins.

Testing it

Check the unit out before fitting it into the case. Apply 3-5V DC to the BAT1 terminals via a spare 1kΩ resistor and measure the voltage across that resistor with a DMM. You should get 0.5-0.75V. If it's much less, check the supply polarity and failing that, soldering and component placement on the PCB. If the reading doesn't drop below 1V after a few seconds, that suggests a short circuit or other problem (eg, incorrectly oriented component) which you will need to look for.

Assuming all is well, turn the pots all the way down, connect up the battery directly and attach a microphone and some sort of amplifier, as long as it has a 'mic' input with either an XLR socket or you have an adaptor.

Switch on and speak into the microphone; check that the output sounds OK.

To test the Li-Po charger, leave the battery connected and plug in the charging cable. Unless the cell is already fully charged, LED1 will light. You can monitor the battery voltage with a DMM; it should rise to 4.2V (this might take a while if it's quite flat to start with).

Drilling the case

A drilling template and front panel artwork can be downloaded from the *EPE* website. Use these to mark the hole positions and drill them all to the sizes shown. The holes will need to be accurately placed because the board only just fits in the case when they are in the right positions.

The largest (XLR) holes will need a tapered reamer – even so, you may still need to use a round file to finish them off (many reamers only go to 20mm).

Note that there won't be much 'meat' left along the rim of the case where these holes are placed, as the connectors must mount quite high for the PCB to clear the bottom of the case.

You'll also need to file flat the lip of the case lid where it would otherwise interfere with the XLR sockets.

Putting it all together

Now for the tricky part, shoe-horning the board into the case. It's a tight fit (deliberately!).

First, cut a sheet of *thin* insulating material (eg, cut from a PET milk bottle) and place it inside the base of the diecast box, to prevent the PCB from shorting to it. If there are any particularly sharp solder joints, you can put some electrical tape over them which will stop them from puncturing this insulating layer.

Next, temporarily remove the locking tab from the female (mic in) XLR socket by pressing it down and pulling it out.

Now feed the RCA socket through its hole in the side of the case. It's then a matter of rotating the PCB and pushing it down so as to get the XLR connectors into their holes. Don't force it; it's a very tight fit. You may even need to enlarge some of the holes in the case side before it will go in.

You may also find that you have to bend the XLR connectors a little so that their lip does not prevent that end of the board from sliding into place. Don't overdo it though, you could damage the PCB.

If the board doesn't want to go in, check that the corner cut-outs have been filed correctly and that it isn't hitting the bottom of the case, which suggests misaligned holes that will have to be enlarged further.

Once it pops in, fit the four screws to hold the XLR connectors in, this also holds the PCB in place, and replace the XLR locking tab by pushing back in.

The diecast box provides the best shielding against hum and so on if it is connected to the circuit ground. This normally occurs through contact between the shield of the 3.5mm or RCA connector, but depending on how large you've made the holes, they may not make reliable contact.

In this case, the easiest solution is to replace one of the XLR mounting screws with an M2 × 10mm machine screw and nut and use this to attach a solder lug on the inside, under the nut.

You can then run a short wire from this lug to a convenient 0V point on the PCB below (eg, a resistor lead connected to ground). This is not critical, but it's a good way to ensure that the shielding is most effective.

Before putting the lid on, connect the battery. The Li-Po cell can be attached under the lid with double-sided tape, in a position where it will clear the pots and LED. It's then just a matter of cutting out the four holes in the lid label, glueing it onto the lid, then screwing the lid on and the assembly is complete.

Your *Mini Mixer* is now ready to use.

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TechnoTalk

Cheap batteries – bargains or duds?

Mark Nelson

Batteries – it's a component we all take for granted, we use them by the million – but they aren't cheap. Do you go by brand or price when you purchase yours? And which names do you trust most? Your gut instinct may be mistaken, as Mark Nelson explains.

DESPITE the growing use of rechargeable batteries, we still buy plenty of the disposable type. It is estimated that there are 35 million households in the UK that use batteries, with a spend of around £105 each per year. According to C&M Research, the average household's annual use is 20 to 30 batteries, and this figure continues to increase. Electronicists like us tend to go through far more of them, so how do you avoid making bad choices?

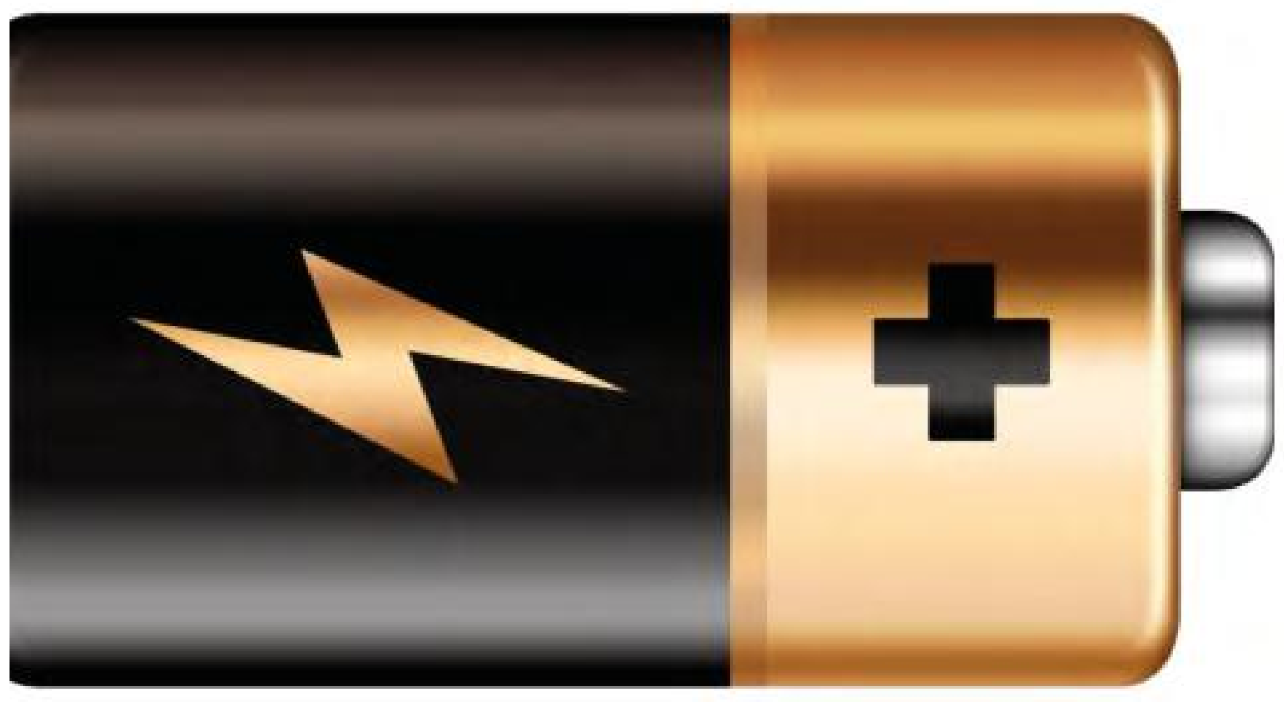
Big brands

The UK battery market is dominated by a small number of manufacturers, with Duracell, Panasonic and Energizer being the most notable. Other top brands include Eveready (the new name for Ever Ready), Samsung, Memorex and Pifco (originally the Provincial Incandescent Fittings Company). None of these firms actually makes domestic batteries in the UK, and most sold in Britain come from the USA or the Far East (China, Indonesia and Japan for instance).

Although most brands are now global, this does not mean that the products are made to the same quality standards, and some of the products intended for sale in developing markets are less reliable or contain a higher level of toxic chemicals. These sub-standard products can turn up over here in corner stores and 'pound shops'. They are generally not worth buying, particularly the metal-cased CR coin cells used in watches. When it comes to choosing conventional tubular batteries, it's well worth checking their markings to see where they were made (there's a clue when the batteries do not carry the crossed-out dustbin symbol).

Bogus batteries

More insidious are the outright fakes. Duracell products have been counterfeited for at least 20 years and an amusing lookalike is GreenStar, which has identical colouring to the copper-and-black Duracell, but the power charge checker feature is merely printed on with paint! But should you avoid buying the fakes if they are cheap? Could the much lower price make them still a good buy? Unlikely – if they leak or swell (as they surely will), they can ruin the battery clips by corrosion and possibly destroy your equipment. They don't last as long as proper batteries and rechargeable ones lose their ability to hold a charge after a few weeks. Net result: you end up spending more money on buying extra fakes than on genuine branded ones. You can learn more on this excellent website: **www.thelongestwayhome.com/resources/How-to-spot-fake-batteries.html**



Research on the web

Still not convinced? A splendid fellow who has an interest in low-power sensors designed a rather ingenious PIC-based test bench to measure the service life of 'pound shop' AA-size batteries. His verdict: batteries priced twice as dear last three-and-a-half times as long as the cheapies. Moreover, alkaline cells deliver more than twice as much power as their zinc chloride equivalents – and they have a much more stable terminal voltage too. Look at it this way; the cost of running a two-cell torch with cheap zinc chloride batteries is 10p/hour and the cost of running the same torch with more expensive alkaline cells is 5p/hour.

Using akalines, you need to change them one third as often, with a much-reduced risk that the battery will leak corrosive liquids. You can check out his test equipment, view the online videos and discover the brand names involved at his website. Go to: **http://simple-living-in-suffolk.co.uk** and then enter the word Poundland in the search box at top right. I cannot show a direct link for legal reasons that you will understand when you see the page's URL. If the page has been banned when you read this, I'm sure that Google will still have a cached copy of it!

Do your bit

The Waste Batteries and Accumulators Regulations 2009 requires an increasing proportion of portable batteries placed on the UK market to be collected for recycling. The rules also prohibit waste industrial and automotive batteries going to landfill or incineration. Most supermarkets and shops that sell batteries now have containers where you can drop used batteries for recycling. You can find your nearest location by entering your postcode at: **www.batteryback.org/battery-collection.html**

The Environment Agency's recycling target for 2013 was 30 per cent of batteries sold to be recycled, reaching 45 per cent by 2016. Figures for 2013 do not have to be submitted until 31 May, but in March declared returns had already reached 28.9 per cent. This sounds very creditable, but you are probably wondering what actually happens to the batteries you drop off at these recycling points?

BatteryBack aspires to be the nation's favourite battery recycler and it explains that they send them to the Belgian industrial waste disposal company Revatech. The firm's recycling process for alkaline and zinc-carbon batteries separates out the magnetic (steel) and non-magnetic (zinc and brass) metal elements, recycles the different components of the 'black mass' (zinc, carbon and manganese), and reprocesses the plastics. The overall recycling rate is at least 55 per cent of the gross weight of the batteries treated.

Second life

According to Duracell, a third of batteries are thrown away prematurely – batteries that could be given a second life. So the firm is encouraging consumers to swap out part-used batteries instead of binning them, using the 'power check' function on its Ultra Power batteries as part of a partnership with the Energy Saving Trust. Duracell claims that some high-drain devices such as digital cameras or MP3 players may stop working before a battery's power is used up, due to a power default switch inside the device, which can leave up to 66 per cent of battery power unused. Its campaign encourages customers to use the power check function to find out if a battery still has enough energy to be used in low-drain devices such as alarm clocks or TV remotes. You can see their online video at: **http://youtu.be/JglYXZgP740** which shows a giant Duracell Bunny being created out of wire, LED lights and of course a huge bank of reclaimed batteries.

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EVERYDAY PRACTICAL ELECTRONICS is offering its readers the chance to win one of three Microstick for 3V PIC24F K-series (#DM240013-1). This Microstick is an easy-to-use, flexible USB-powered development platform. It's the perfect solution for those looking to get started with Microchip's lowest-cost 16-bit microcontroller families, PIC24F 'KL' and 'KA', designed for extremely cost-sensitive consumer, medical and industrial applications.

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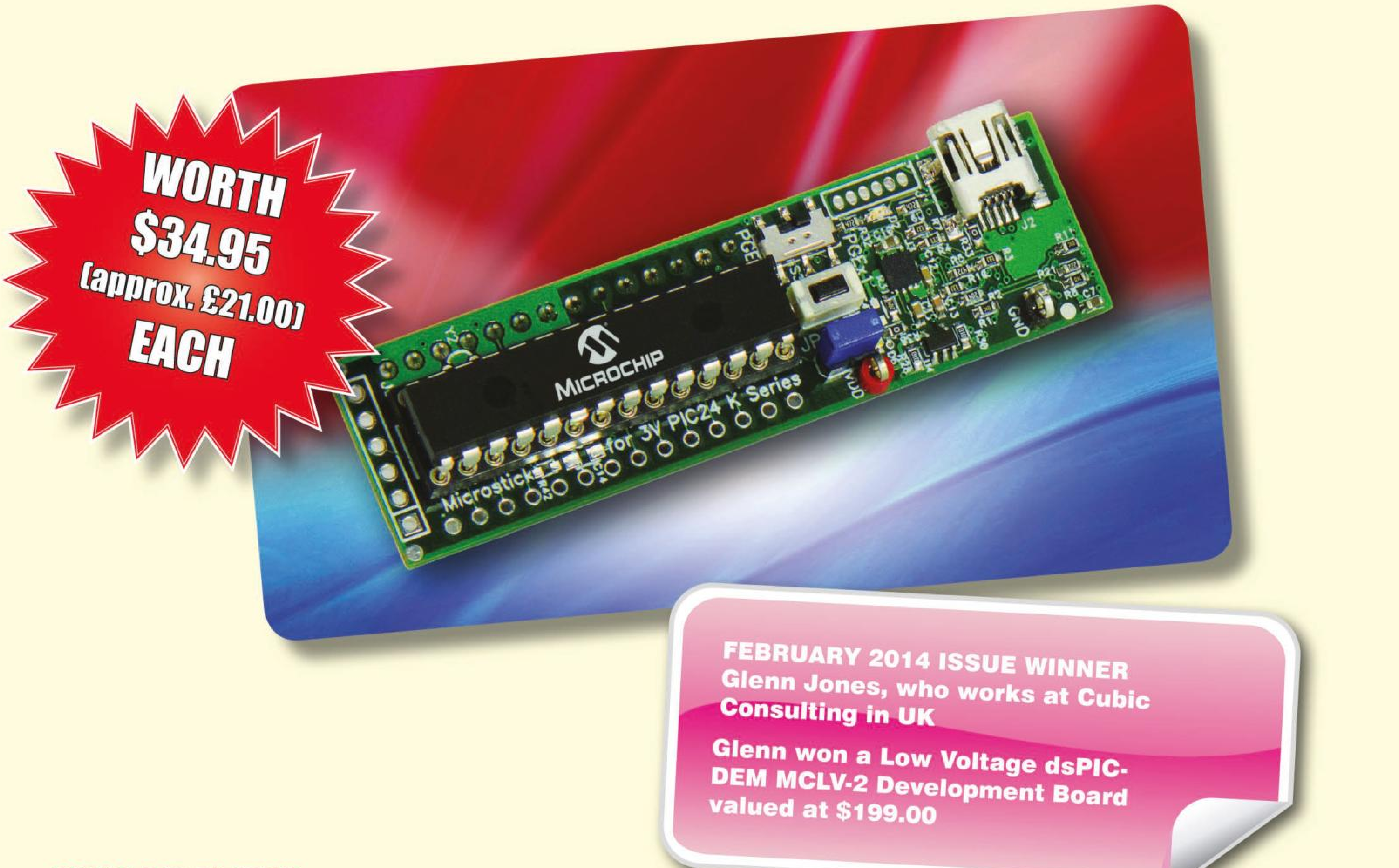

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Adding Voltage and Current
to the Bits'n'Pieces Battery

AMPS DC
8.45
SCA
14.38
VOLTS DC

There are three easy ways to add voltage and current meters to our battery charger. One is relatively expensive, one is dirt cheap and one is in the middle. Let's look at these in turn.

(a) Using mechanical (moving coil) panel meters

This is arguably the easiest way to go because you can buy panel meters already set up to read exactly what you want. For example, the Altronics Q0421A panel meter reads 0-20A 'straight out of the box', while their Q0523A model reads 0-20V. The other big advantage of these panel meters is that they don't require power to operate, so that also simplifies things somewhat.

All you need to do with these meters is cut suitable holes in the charger case, mount the meters and then connect the ammeter in series with the output and the voltmeter in parallel with the output.

Bingo – simple – but this is the most expensive way to go and it's not all that accurate, simply because the meter scale only lets you read to about the nearest amp or volt. In many cases, this might be all you need, but sometimes you want more accuracy than that.

Unfortunately, unless you can snaffle a couple of suitable meters from junked equipment, you're going to be up for around £10 per meter. That's a significant proportion of what the charger without meters would cost!

When we said 'suitable' meters a moment ago, you'd probably be aware that just about all meters can be set up to read whatever you want them to. The same basic meter, with an appropriate shunt (a low-value resistance in parallel) will read whatever current (or parts thereof) you set it up to read, or with appropriate multiplier (a much higher resistance in series with the meter), whatever voltage you want.

A typical moving coil meter without shunt or multiplier might read, say, 1mA full scale. This meter would have a resistance of 210Ω. But if you put

Meters Charger

Last month, when we put together our ***Bits'n'Pieces Battery Charger***, we promised to show how to add meters to show both current and voltage. Sure, it's getting out of the realms of a dirt cheap charger but, what the heck...!

by Ross Tester

another 210Ω resistor in parallel with it, it will read 2mA full scale – half the current flows through the meter, half through the shunt.

The lower the value you make that resistor in parallel, the more current flows through it, but the current through the meter movement (and therefore the reading) will stay in proportion.

To read high currents, the vast majority of current needs to flow through the shunt, so the values of shunt resistance become very low indeed – fractions of an ohm.

It's similar with voltage: the resistance of the meter movement is still 210Ω, so if you put, say, a 20kΩ resistor in series with it, the voltage will divide in the ratio of 210:20,210 and if there is 20V across both the meter and multiplier, the meter will read 20V (or very close to it).

So as you can see, if you can find a couple of old meters and (carefully!) work out what their resistance is by slowly increasing the current through them until they read full scale (also called their sensitivity), you can use Ohm's law to work out their resistance (ie, R=V/I), you can then make up your own shunts and multipliers to make the meters read what you want.

Before we finish with mechanical panel meters, you might have heard of 'expanded scale' meters. These are invariably standard meters which have shunts and multipliers set up so that they read only a limited range of values – for example, 10-15V – which means that they don't start reading until the voltage exceeds 10V and it reaches maximum scale at 15V. This gives much greater accuracy as the divisions on the scale are further apart (or there are many more of them).

00.1
QM-1502
V⎓
500
OFF
500
V~
200
A⎓
200
20
2000 m
200 m
2000 k
200k
20k
2000
200
200µ
2000 µ
20 m
200 m
10A⎓
hFE
E C B E
PNP
NPN
COM
VΩmA
10A MAX
A

These little multimeters are so cheap you could justify using one as a dedicated panel meter. Powering on and off could be a problem – unless you use the neat little circuit from last month!

(b) Using cheap DMMs

This is the lowest-cost method and for many people, it will be more than sufficient. In fact, last month, we showed you how to add auto power-down to cheap (a few pounds) digital multimeters.

You can set it to read what you want (eg, 20V or 10A) and measure the voltage or the current in the normal way – voltage in parallel, current in series.

At the price, you could afford to have two of these meters dedicated to read voltage and current, simply by leaving the dial set and turning the meters on when needed.

But it doesn't matter if the meters are turned on or not when using the battery charger, charging current will still flow through the shunt in the meter so it will make precious little difference, and as a voltmeter, it is in parallel with the output so might as well not be there.

Unfortunately, you cannot power the multimeter from the same source as being measured, but with the simple modification mentioned last month, the 12V battery in these cheapies should last for quite a long time.

If you got really enthusiastic, you could work out a way to mount these DMMs inside the charger case and bring the 'power' pushbutton out to the case.

Incidentally, the rotary switch on a multimeter merely selects various shunts and multipliers to read amps and volts over various ranges. To measure resistance (ohms) it uses an internal battery to push a small current through the resistor and reads that current but displays it as 'resistance'.

To measure AC voltage or current, in the vast majority of cases the AC is rectified inside the multimeter and the resulting DC voltage or current is displayed on an 'AC' scale.

(c) Using digital panel meters

This is the preferred approach – it will cost more than using cheap DMMs, but not as much as using mechanical meters. In our case, we are using a couple of Oatley Electronics' 3.5-digit Digital Panel Meters (DPM1). One is set up to read volts, the other amps – just the same as the panel meters above.

However, these digital panel meters do need power and, once again, you cannot simply power them from the device being measured. Luckily, the power they need to operate is 'flea power' –just a couple of milliamps. If you add Oatley's K-265 Interface Kit (K265) it will supply all the power you need from the battery charger itself.

0
5
10
15
20
V
10
20
30
40
50
µA

One of these moving-coil meters reads 0-20V, the other 0-50µA. But they are exactly the same meter movement – to read voltage, you add a series multiplier; for current, you add a parallel shunt. Obviously scales are changed to reflect the different measurements.

Now we're talking! These £5 digital panel meters from Oatley Electronics (Cat no DPM1) can be set up to read current or voltage – which is exactly what we're after.

3.5 or 4 digits?

Before we get into it, though, we can already hear the question: 3.5 digit? I can see four digits!

It's long been a source of confusion – but the explanation is pretty simple. It's more expensive to produce a meter which reads 9999 (a 4-digit display), so many are made to read 1999 instead.

Therefore, a 3.5-digit display can show any value up to 1.999 (or 19.99, 199.9, 1999). In our case, we want it to display up to 20A and 20V – well, it can just about do that – it can never *quite* get there (it's 1mV or 1mA short!).

OK, so how do you use them?

Basically, using a digital panel meter is very similar to using a mechanical panel meter, as detailed above. The instructions supplied with the meter show how to set it up as a voltmeter, with a series multiplier, or an ammeter, with a parallel shunt (now where have we heard those terms before?).

Building the interface board

This is simply a matter of following the diagrams supplied with the kit and on the PCB component overlay. Just a couple of tips: three miniature transformers are supplied; it doesn't matter which one goes where.

However, you will find there are three pins on one side and two on the other – which determines which orientation they have. And before soldering in the PCB-mounting terminal blocks, slide them together so they link. Finally, don't mix up the four 1N4148 small signal diodes with the 9.1V Zener – the circuit won't work if you do – and also note that the Zener mounts in the opposite direction to the other four diodes.

One other point to note: the overlay on the PCB was different to that supplied in the instructions – the overlay is correct, with a 2k trimpot (VR3) instead of a fixed resistor (R6 – 390Ω).

Once completed and before the interface is connected to the digital panel meters, we need to adjust the output voltage (using VR3) to get 9V.

Using a 12V battery, connect power to the interface board and adjust VR3 to get as close as you can to 9V at the output 'V' and 'I' DPM terminals (they should be identical). Once done, disconnect the battery and put the interface board aside until you're ready to assemble everything.

Preparing the box

From here on, we are assuming that you are using the preferred approach.

The first task is to determine where you want to mount the DPMs. The main thing to remember is to keep them away from the 'bitey bits' on the left side of the box – we chose a spot on the top right.

Mark the positions of your meters, remembering that there is an escutcheon which is larger than the meter itself. There should be around 20mm between the meters if mounting them side-by-side.

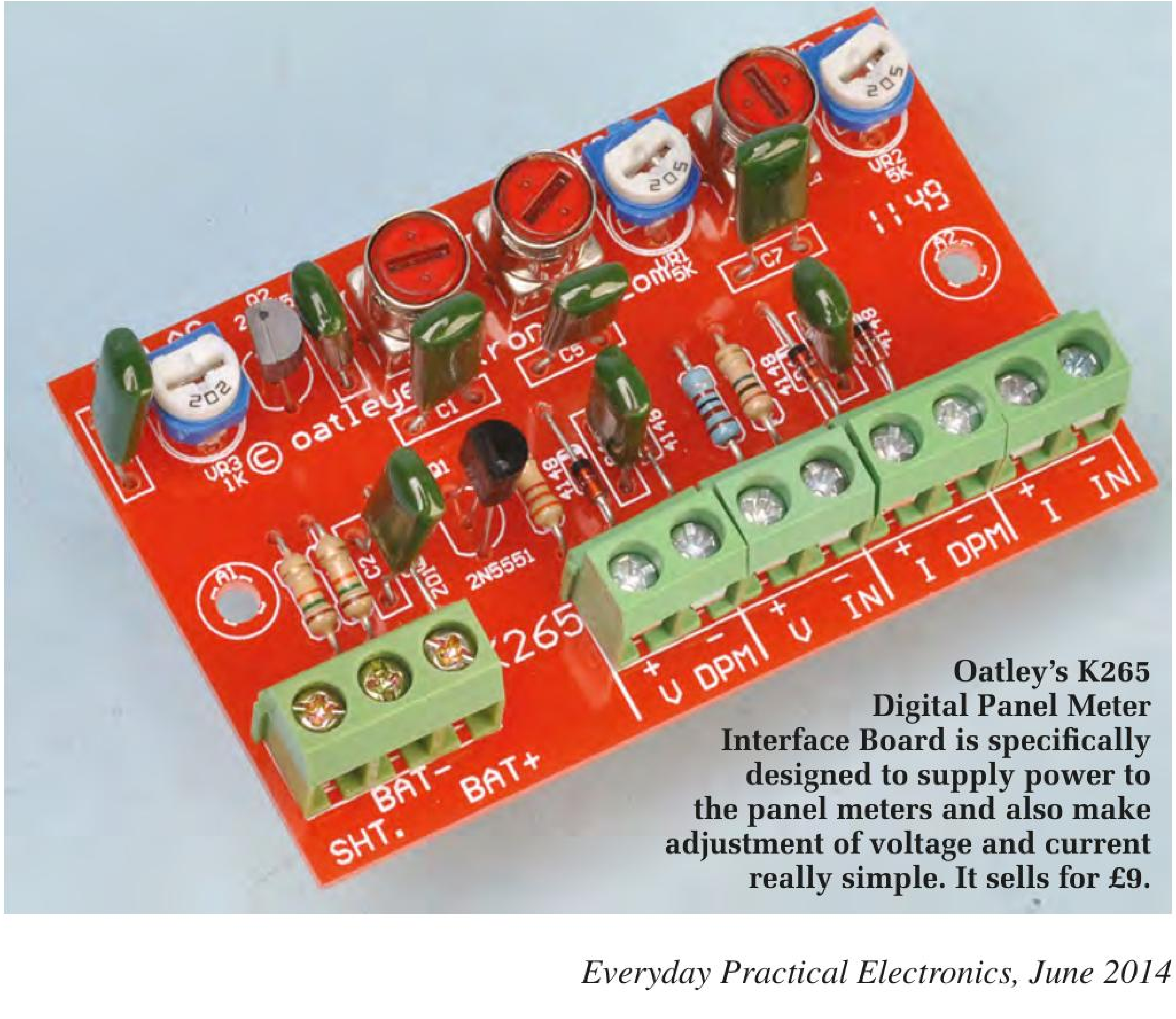
Mark the two cutouts, which should be 50 × 25mm, in your chosen positions, and cut them out.

Whether you use the tried and true method of drilling a lot of small holes and cutting out the panel (filing it smooth), drilling a larger hole and nibbling out the panel or perhaps using a metal blade in a jigsaw, make sure that you don't get any swarf in the case. In fact, it's a good idea to open the case right out – that means your blade or drill can't do any damage either.

Mark the four holes for each of the mounting screws (attached to the escutcheon) and drill them out to 3mm. These holes are centred around the display, 60mm wide and 24mm deep.

Remove the nuts from the displays and separate the back halves from their escutcheons. Make sure the four bolts attached to the escutcheons fit easily through the mounting holes and that the escutcheons cover the edges of the cutouts.

Before we mount the DPMs we need to modify them slightly to act as the 0-20V and 0-20A meters.



Oatley's K265 Digital Panel Meter Interface Board is specifically designed to supply power to the panel meters and also make adjustment of voltage and current really simple. It sells for £9.

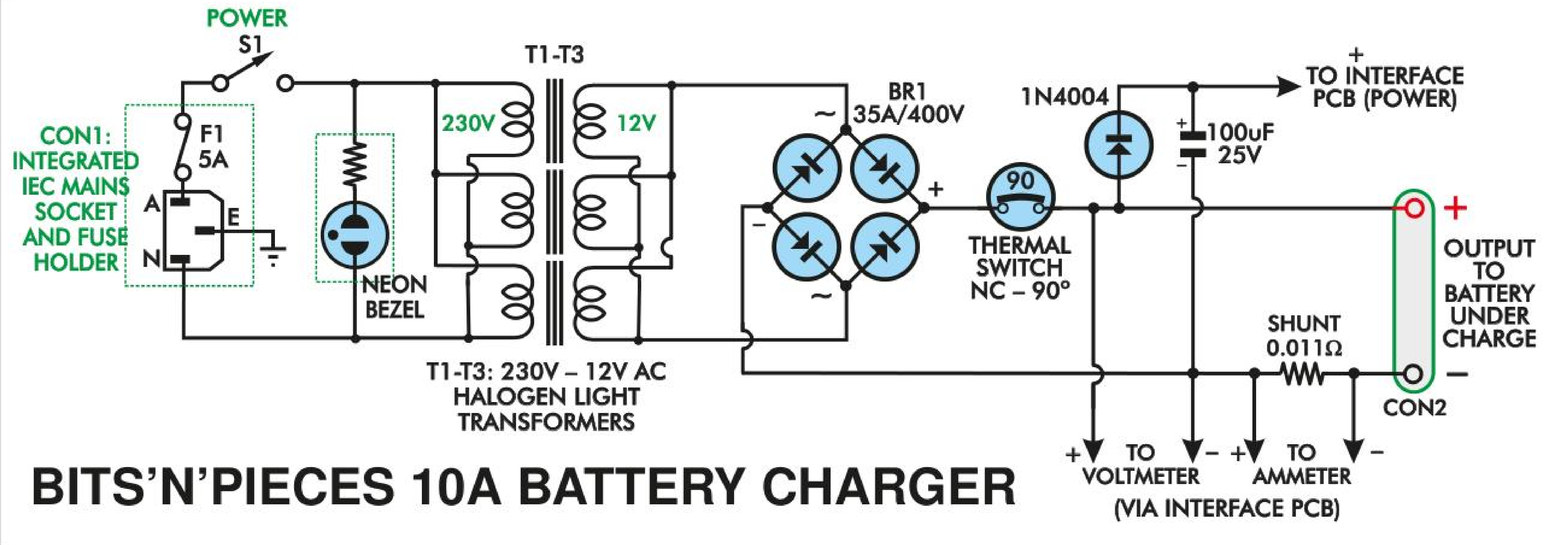

POWER
S1
CON1: INTEGRATED IEC MAINS SOCKET AND FUSE HOLDER
F1 5A
A
E
N
NEON BEZEL
T1-T3
230V
12V
T1-T3: 230V – 12V AC HALOGEN LIGHT TRANSFORMERS
BR1 35A/400V
~
+
–
1N4004
90
THERMAL SWITCH NC – 90°
100uF 25V
+ TO INTERFACE PCB (POWER)
+
OUTPUT TO BATTERY UNDER CHARGE
–
SHUNT 0.011Ω
CON2
+ TO VOLTMETER –
+ TO AMMETER –
(VIA INTERFACE PCB)
BITS'N'PIECES 10A BATTERY CHARGER

Fig.1: the main differences between this and last month's charger circuit is the addition of the 0.011Ω shunt resistor, adding connections for the voltmeter and ammeter panel meters and a smoothed DC supply.

Modifying the DPMs

As supplied, the DPMs are set up to read 200mV (well, actually 199.9mV). To make them read 20V we need to change the multipler and move the decimal point.

Rather than try to disassemble the panel meter PCB (which is not easy) and reassemble it (which is almost impossible!) provision is made on the interface board.

You would have earlier (during construction of the interface board) selected a 1MΩ resistor (R1) so the DPM would read 20V; all you need do is connect the DPM to the interface board (both power and voltage input), connect a known voltage source of, say, 12-20V DC to the BAT+ and BAT– terminals of the interface board and adjust the 'V CAL' trimpot (VR1) to that voltage.

For example, you could use a 12V SLA battery and your digital multimeter to get the known voltage.

Changing the decimal point is not quite so simple. It is wired to suit a '199.9' reading; we want it to suit a '19.99' reading. Theoretically, that's just a matter of changing a link on the PCB from P3 to P2 – but as we said earlier, disassembling the PCB to get at the P3 link is not a good idea.

Instead, we are suggesting you carefully cut a track on the PCB and solder a link between that cut track and the right-hand pair of P2 pads – the photo below shows the detail.

To solder to a solder-masked track, carefully scrape some of the green mask off the track to reveal bright copper and equally carefully solder to that. Be careful – it doesn't take much heat to lift thin tracks.

The current meter needs to have the same decimal point modification because we want it to read up to 19.99A. Once again, the interface board is set up to allow it to read this with a suitable shunt connected.

The shunt is actually two parallel-connected 1.5m lengths of resistance wire (supplied in the interface kit). A single length of this wire has a resistance of 0.0146 ohms per metre, so 2 × 1.5m lengths in parallel will have a resistance of 0.011Ω.

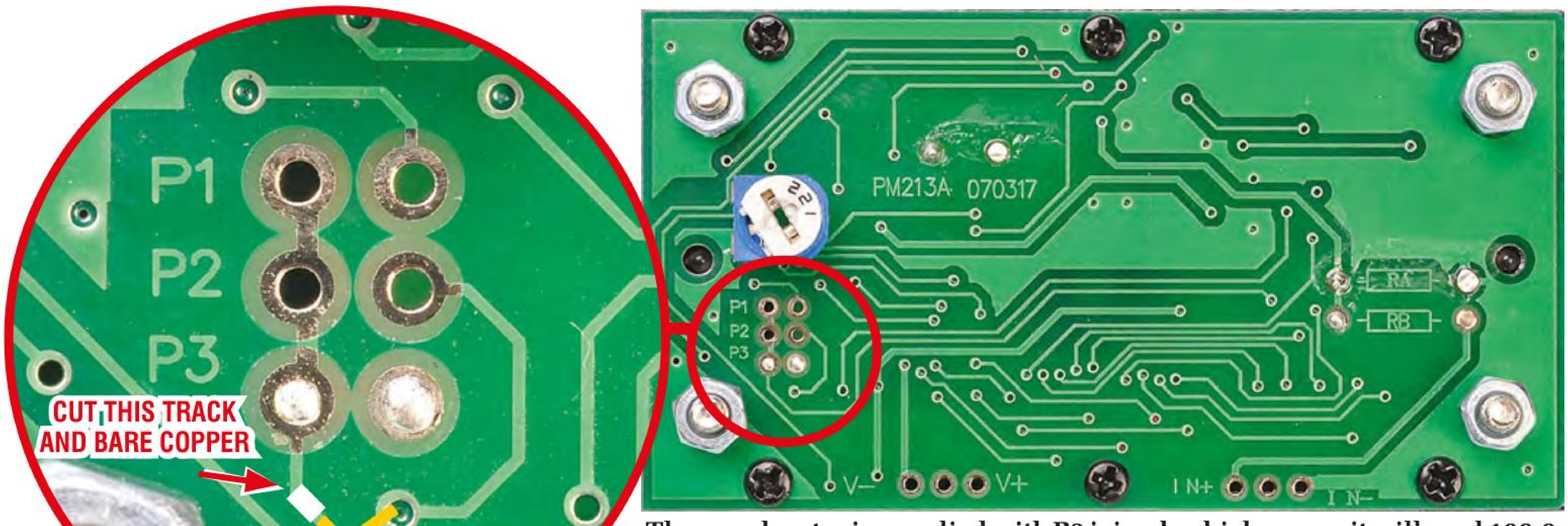
If reading 20A, this will result in a voltage drop of 0.22V. While this is slightly too high (it should be 0.199V) this error can be corrected via the use of the 'I CAL' trimpot, VR2.

Connecting the shunt

The shunt is simply wired in series with the charger output. You need to break the connection between the bridge rectifier and the negative output terminal and wire the shunt in its place.

A pair of much thinner wires (as thin as you like!) connect from each end of the shunt to the 'SHT' and 'BAT–' terminals on the interface board.

We wound the shunt into a pretty small coil and placed it near the output terminals. A two-way terminal block is provided in the kit, but we replaced this with a much larger 4-way block – this is


P1
P2
P3
CUT THIS TRACK AND BARE COPPER
JOIN
PM213A 070317
RA
RB
V–
V+
IN+
IN–

The panel meter is supplied with P3 joined, which means it will read 199.9. To make it read 19.99, P2 must be joined instead. As it is very difficult to disassemble and reassemble the PCB, we suggest cutting the track shown, baring some copper and soldering a link between the point shown and the bare track.

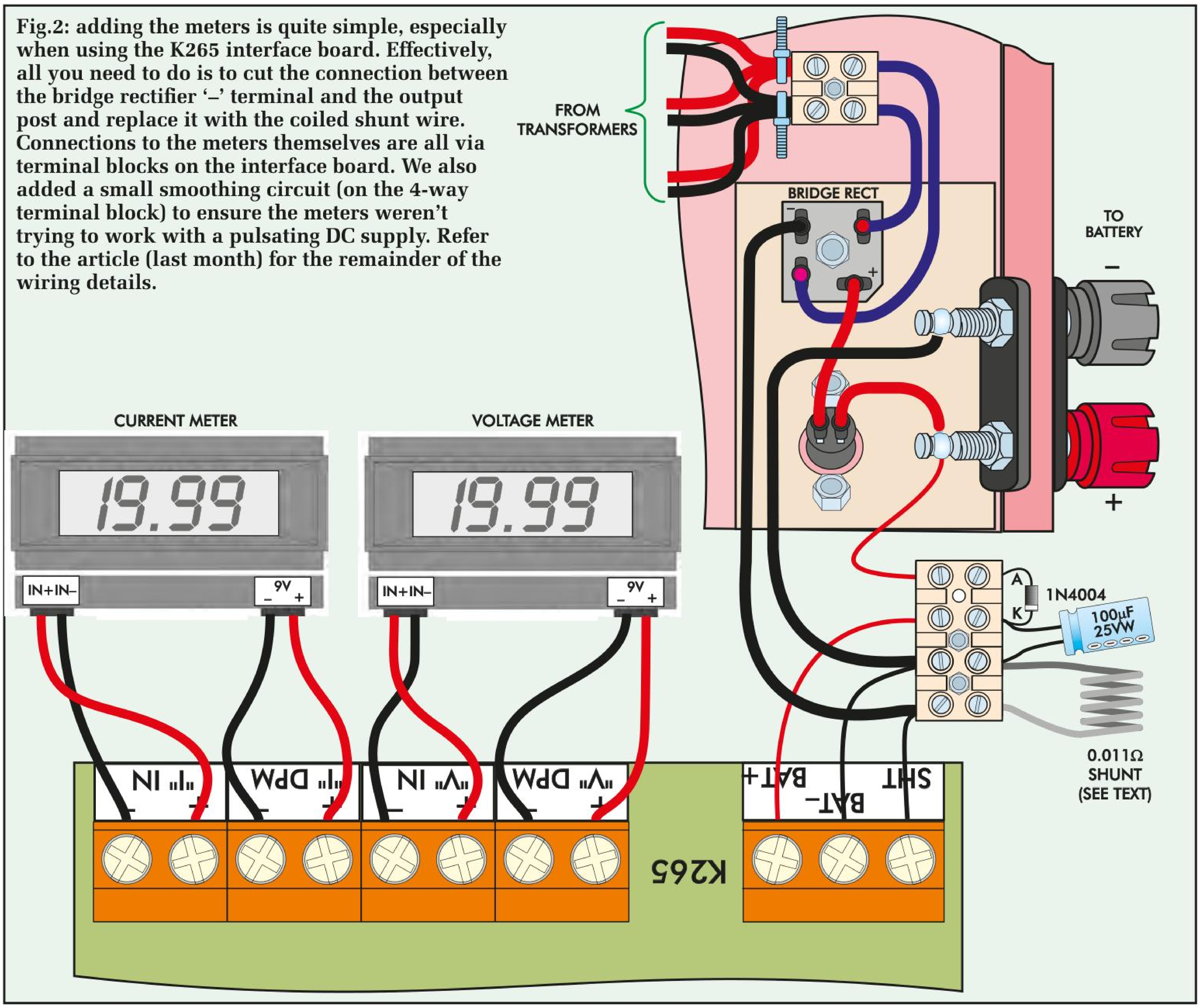


Fig.2: adding the meters is quite simple, especially when using the K265 interface board. Effectively, all you need to do is to cut the connection between the bridge rectifier '–' terminal and the output post and replace it with the coiled shunt wire. Connections to the meters themselves are all via terminal blocks on the interface board. We also added a small smoothing circuit (on the 4-way terminal block) to ensure the meters weren't trying to work with a pulsating DC supply. Refer to the article (last month) for the remainder of the wiring details.

much easier to connect to because the shunt wires (and the output wires) are quite thick and securing them in the small terminal block is not the easiest thing in the world.

Besides, we wanted another two terminals for some more components.

Connecting the multiplier

It's already done for you – on the interface board!

Connecting power from the charger

As you would realise, the output from the bridge rectifier is pulsating DC and there is very little in the way of smoothing on the interface board.

To make use of the charger output, we used a diode in series (to isolate the supply from the charger output) and a small electrolytic capacitor to give a smooth supply for the interface.

Again, this can be placed wherever it will fit – the same terminal block can hold these two components.

Parts List – Adding Meters to the Bits'n'Pieces Battery Charger

- 2 3.5-digit panel meters (eg, Oatley Electronics DPM1)
- 1 DPM Interface Kit (Oatley Electronics K265)
- 1 100µF 25V electrolytic capacitor
- 1 1N4004 power diode
- 1 4-way large terminal block
- Hookup wire
- Nuts, screws and washers as required.

Connecting the modules

These are pretty-much self explanatory. You have four terminal blocks on the interface board – the ones labelled 'V' are for the voltmeter and the ones labelled 'I' are for the current meter. Fig.2 shows the connections – 'V' and 'I' DPM supply power; + to + and – to – respectively.

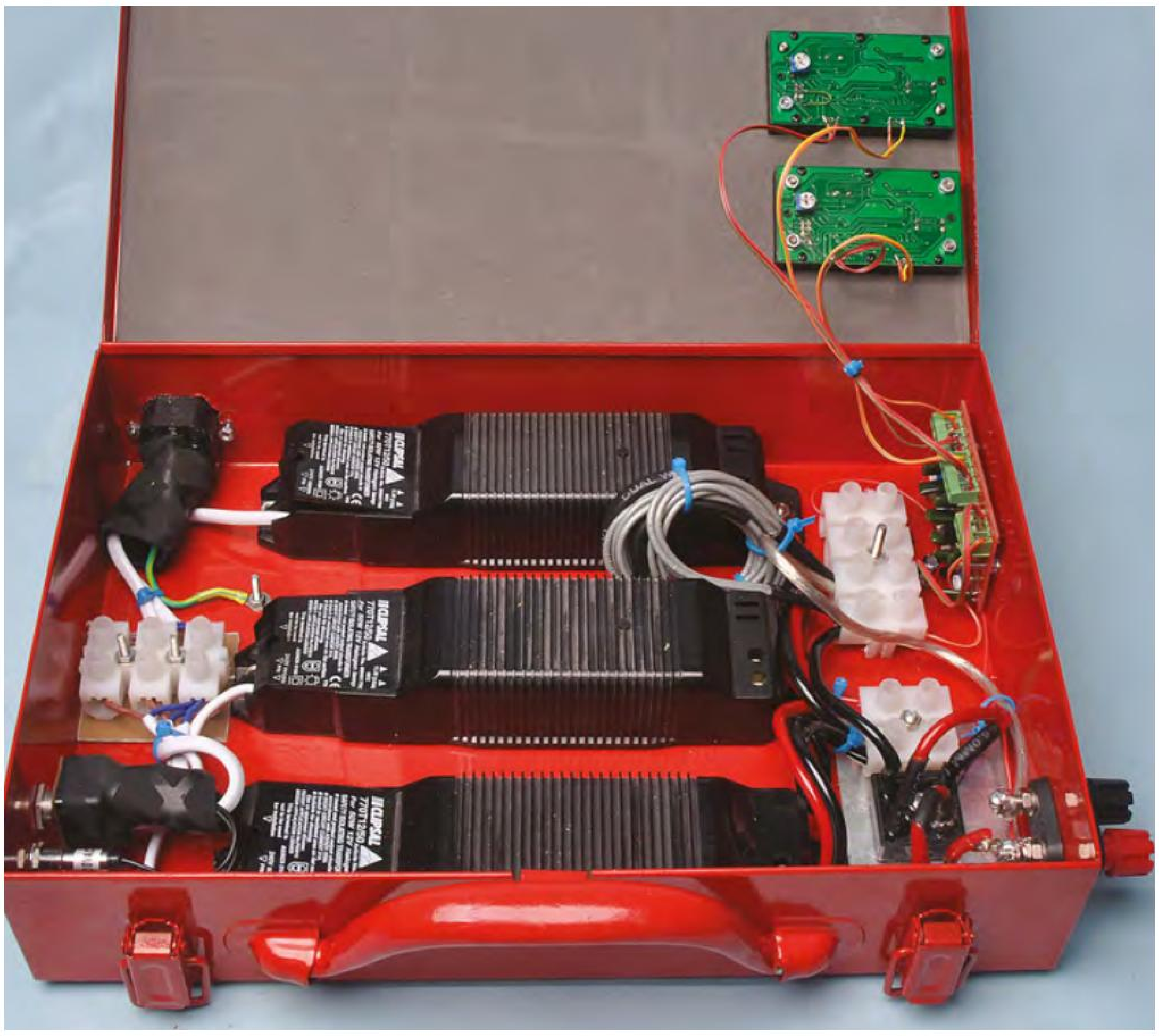
'V IN' and 'I IN' are the connections for the measurement terminals (again, + to + and – to –).

The only slight wrinkle here is that the solder pads on the modules are very small. Be careful soldering to them (ignore the centre terminal in all cases).

It will probably be easier if you connect the modules and shunt before screwing everything into place. Don't forget, the wire between the interface and panel meters doesn't have to be at all thick. We used rainbow cable.

The only thick cables needed are those required to pass the battery

(Above): here's how we 'wound' the shunt resistor. It consists of two 1.5m lengths of insulated resistance wire, wound together. Final resistance is 0.011Ω. Actual number of turns is immaterial – just make it as small as practical! The 2-way terminal block (which comes with the kit) was later replaced with a much larger 4-way block, which also connects the power supply components.



(Right): the new components to drive the panel meters are all mounted on the right side of the case, as seen here. Ensure there is plenty of clearance between the meters and interface board/terminal block when the lid is closed and that there is enough wire to avoid them being stretched.

charging current – most of what you need should already be in place from the 'meterless' version of last month. In fact, the only extra length of heavy duty cable we needed was to connect the terminal block (shunt connection) back to the negative output terminal.

Use cable ties to ensure all cables are secured and won't come adrift, especially when the case lid is opened.

Where do you mount the interface?

Wherever you can! There should be enough space for it (and the terminal blocks for both shunt and diode/electro) near the rectifier. You might have to move things around a little bit but there should be tons of room.

We mounted ours on the end of the case and stood it off the surface by the thickness of one nut and washer (see photo above).

Connect everything up, check your wiring twice and you're ready for the smoke test. If you don't get any, you've passed!

To finish off, mark the case with a couple of labels showing which is the voltmeter and which is the ammeter.

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Got an extra transformer?

Not long after the meter-less version was published, the designer received a note from a reader (Charles Tivendale) who told us that he had made a similar charger some years ago, but he used an extra transformer to give improved performance.

It wasn't, as you might expect, simply in parallel with the other transformers. He used the fourth transformer to boost the primary voltage slightly to the other three, thus giving slightly higher secondary voltages.

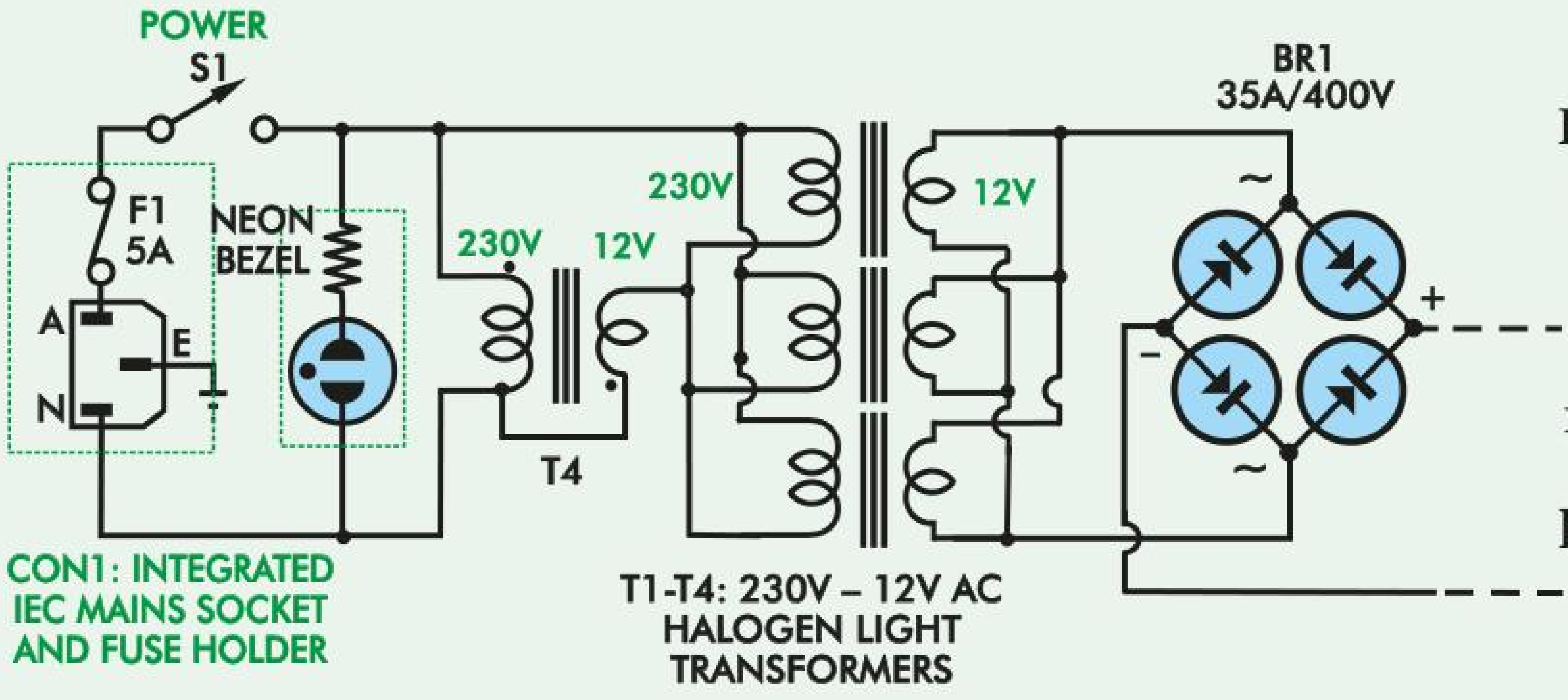
This was done as shown in the circuit below, with the secondary winding of one transformer connected in series with the primary and used as an auto-transformer. In other words, the 230V mains voltage was applied to the primary with the output taken from the 230V + 12V winding, resulting in a nominal 242V output.

This slightly higher voltage was then applied to the primaries of the other transformers, resulting in a slightly higher output voltage to the bridge rectifier.

Naturally, this gave more output from the charger – not a huge amount but enough to make the whole exercise worthwhile (especially if the transformer cost you nothing!).

The phasing of the new transformer windings is important – if you connect them up incorrectly, you'll get less than 220V out. If this happens, simply reverse the connections to the 12V winding.

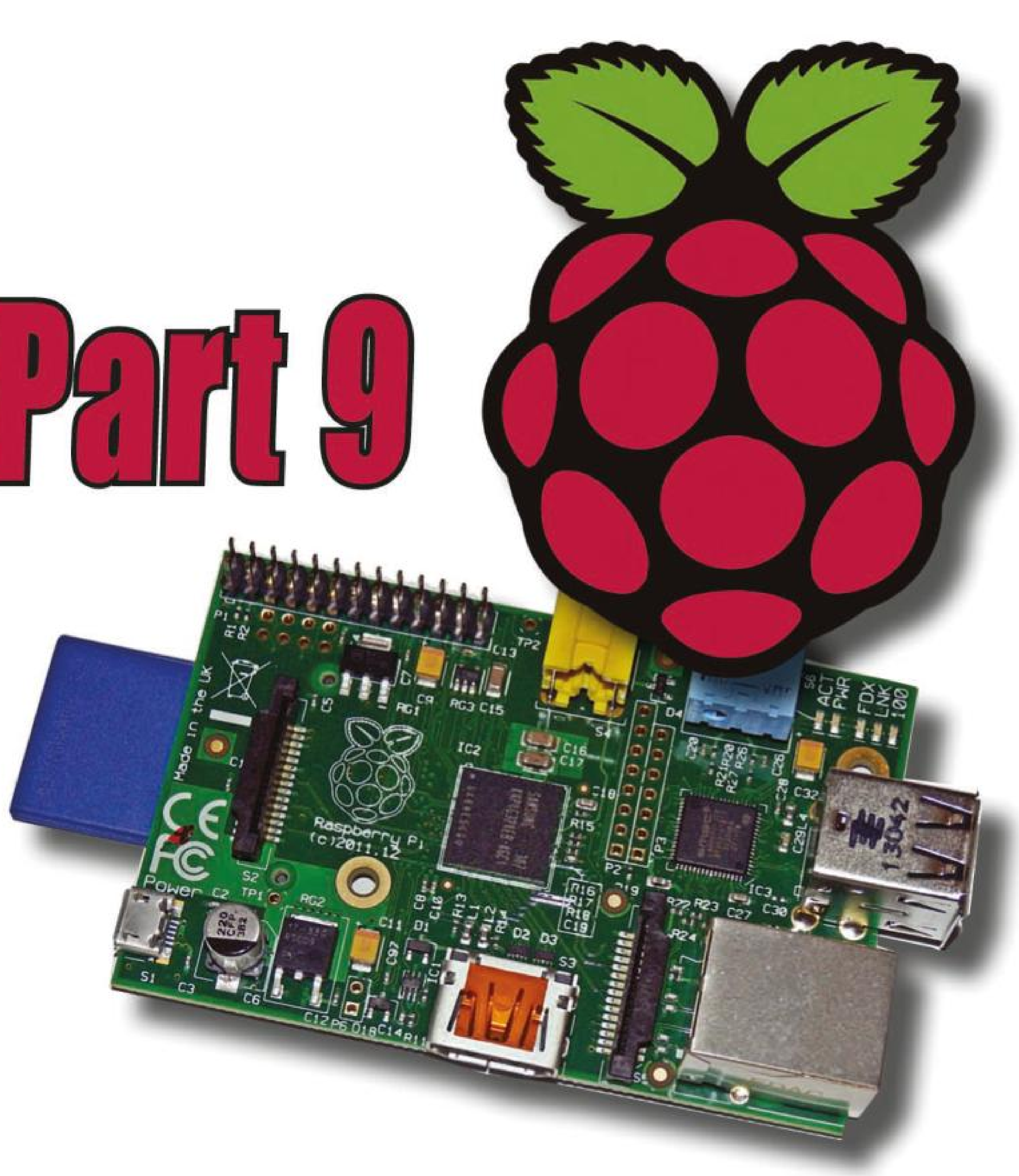
One point to note: as there is no current control on this simple charger, if the battery is fully charged (ie, it's gassing) the extra voltage might be enough to cause an overcharge. Just something to keep your eye on!



Here's how to add an extra transformer (in auto-transformer mode) to give a slightly higher output voltage.

Teach-In 2014 Raspberry Pi – Part 9

by Mike and Richard Tooley



Welcome to *Teach-In 2014* with Raspberry Pi. This exciting series has been designed for electronics enthusiasts wanting to get to grips with the immensely popular Raspberry Pi, as well as computer buffs eager to explore hardware and interfacing. So, whether you are considering what to do with your Pi, or maybe have an idea for a project but don't know how to turn it into reality, our *Teach-In* series will provide you with a one-stop source of ideas and practical information.

The Raspberry Pi offers you a remarkably effective platform for developing a huge variety of projects; from operating a few lights to remotely controlling a robotic vehicle through the Internet. *Teach-In 2014* is based around a series of practical exercises with plenty of information for you to customise each project to meet your own requirements.

The Raspberry Pi is no mean performer; it can offer you very similar performance to that which you might expect from a larger and much more expensive computer system, so don't be fooled by the relatively small price tag. By shopping around you can build a very effective computer system based on a Raspberry Pi for less than £100. However, if you are looking for something more modest and just want to take advantage of the Raspberry Pi as a single-board computer for a particular control application then you can be up and running for a very reasonable outlay.

This series will teach you about:

- **Programming** – introducing you to the powerful Python programming language and allowing you to develop your programming skills
- **Hardware** – learning about the components and circuits that are used to interface microcomputers to the real world
- **Computers** – letting you get to grips with computer hardware and software and helping you understand how they work together
- **Communications** – showing you how to connect your Raspberry Pi to a network and control a remote device using Wi-Fi and the Internet.

So, what's coming up? Regular features of Teach-In 2014 with Raspberry Pi will include:

- **Pi Project** – the main topic for each part will be a project that explores a particular use or application of the Raspberry Pi in the real word. Projects will include shopping for your Pi, set up, environmental monitoring, data logging, automation and remote control.
- **Pi Class** – each of our Pi Projects will be linked to one or more specific learning aims. Examples will include methods of representing and handling data, serial versus parallel data transmission and architecture of a microprocessor system.
- **Python Quickstart** – a short feature devoted to specific programming topics, such as data types and structures, processing user input, creating graphical dialogues and buttons and importing Python modules. We will help you get up and running with Python in the shortest time!
- **Pi World** – this is where we take a look at a wide range of Raspberry Pi accessories, including breadboards, prototype cards, bus extenders and Wi-Fi adapters. We will also help you build your Raspberry Pi bookshelf with a selection of recommended books and other publications.
- **Home baking –** suggested follow-up and extension activities such as 'check this out', a simple quiz, things to try and websites to visit.
- **Special features –** an occasional 'special feature'. For example, how to laser cut your own mounting plate – with additional downloadable resources such as templates and diagrams.

What will I need?

To get the best out of our series you will, of course, need access to a Raspberry Pi. If you don't already have one, don't worry – we will be explaining what you need and why you need it (we will also be showing you how you can emulate a Raspberry Pi using a Windows PC).

This month

In this month's *Teach-In 2014*, our *Pi Project* features the construction of an infrared (IR) camera with an integrated lighting source that's ideal for wildlife monitoring, simple home security applications and general low light-level photography. *Python Quickstart* will show you how you can write HTML files and then render them in your Raspberry Pi's web browser from within your Python code. For good measure, *Pi World* delves into analogue and digital I/O using the popular and versatile Custard Pi 2. Finally, and so that you can check your understanding of the *Teach-In* series so far, we complete this instalment with our very own *Home Baking Quiz.*

Python Quickstart

In this month's *Python Quickstart* we'll be explaining how you can use Python to create an HTML page that can be easily rendered in a web browser. We will also show you how you can get Python to start your local web browser and use it to display an HTML page that has been created by your code. This opens up a number of interesting possibilities, including a way of generating good-looking reports and also creating pages that can be displayed by your own Raspberry Pi when set up for use as a web server (see last month's *Teach-In 2014*).

Writing HTML files

In common with most programming languages these days, Python can easily create an HTML file by simply embedding tags within a conventional text file. The following example generates an HTML file by creating a multi-line string called `html_str` before writing it to a file called `hello.html`. If you open this file in the Rasberry Pi's web browser (eg, Midori or NetSurf – see boxed text) you should see the 'Hello Raspberry Pi' message.

```
# HTML code to be rendered
html_str = """
<html>
<head>
</head>
<body>
<h2>Hello Raspberry Pi!</h2>
</body>
</html>
"""

# Write the html to a file
file = open("hello.html","w")
file.write(html_str)
file.close()
```

There are a few things to note about this fragment of code. First, and unlike most of the Python code that we've met thus far, there's no need to import any library modules. Second, the text that constitutes our HTML file is taken from the multi-line string between the two groups of *three* quotation marks. There are other ways of building a string like this, as we shall see later.

Opening up the web browser

Now, suppose that we want Python not only to write an HTML file, but also to open the file and display it in the Pi's default web browser. The great thing is that this can be done very easily using Python's web browser library module, as shown in the next example:

```
# Import the libraries
import webbrowser
import time

now = time.time()

# HTML code to be rendered
html_str1 = """
<html>
<head>
</head>
<body>
<h2>Time now:
"""

html_str2 = """
</h2>
</body>
</html>
"""

html_str = html_str1 + time.ctime(now) + html_str2

# Write the html to a file
file = open("time.html","w")
file.write(html_str)
file.close()

# Open the web browser and display the file
webbrowser.open("time.html")
```

The Python code creates two multi-line strings, `html_str1` and `html_str2`, and uses the time library module to generate a string containing the current time, `time.ctime(now)`. This is then inserted, between `html_str1` and `html_str2` to make the complete string (`html_str`). This is then written to the `time.html` file. Finally, the `webbrowser` object is opened and the `time.html` file is sent to it.

Web browsing and the Raspberry Pi

Several different web browsers are available for the Raspberry Pi, these are in addition to the default browser, Midori, currently supplied as part of the Raspbian OS distribution. If you need to use the web intensively rather than just as a means of occasionally browsing web pages and for email, you will almost certainly want to upgrade your browser. At the same time, there's a need for a browser that does not overburden your Raspberry Pi and which can fetch and render web pages reasonably quickly.

NetSurf is a good alternative and, like Midori, it is also supplied with current Raspbian distributions. It is the author's preferred browser, but it still has some quite serious problems rendering more complex web pages. Other browsers include Lynx (install using `sudo apt-get install lynx`) and Chromium (install using `sudo apt-get install chromium`). Lynx is designed for fast, text-only web browsing, and this makes it unsuitable for pages with a graphical content. Chromium, by contrast, is a fully featured browser, but you may find that it consumes considerably more of your precious system resources than either NetSurf or Midori.

Aware of the shortcomings of existing web browsers, the Raspberry Pi Foundation has recently unveiled a new web browser capable of supporting the HTML 5 standard. The new web browser is still under development, but is likely to offer multi-tab surfing and optimised image rendering as well as HTML 5 video decoding. It seems likely that the new web browser will be included in future Raspbian releases, so do keep a look out for it.

Using the Python `with` statement

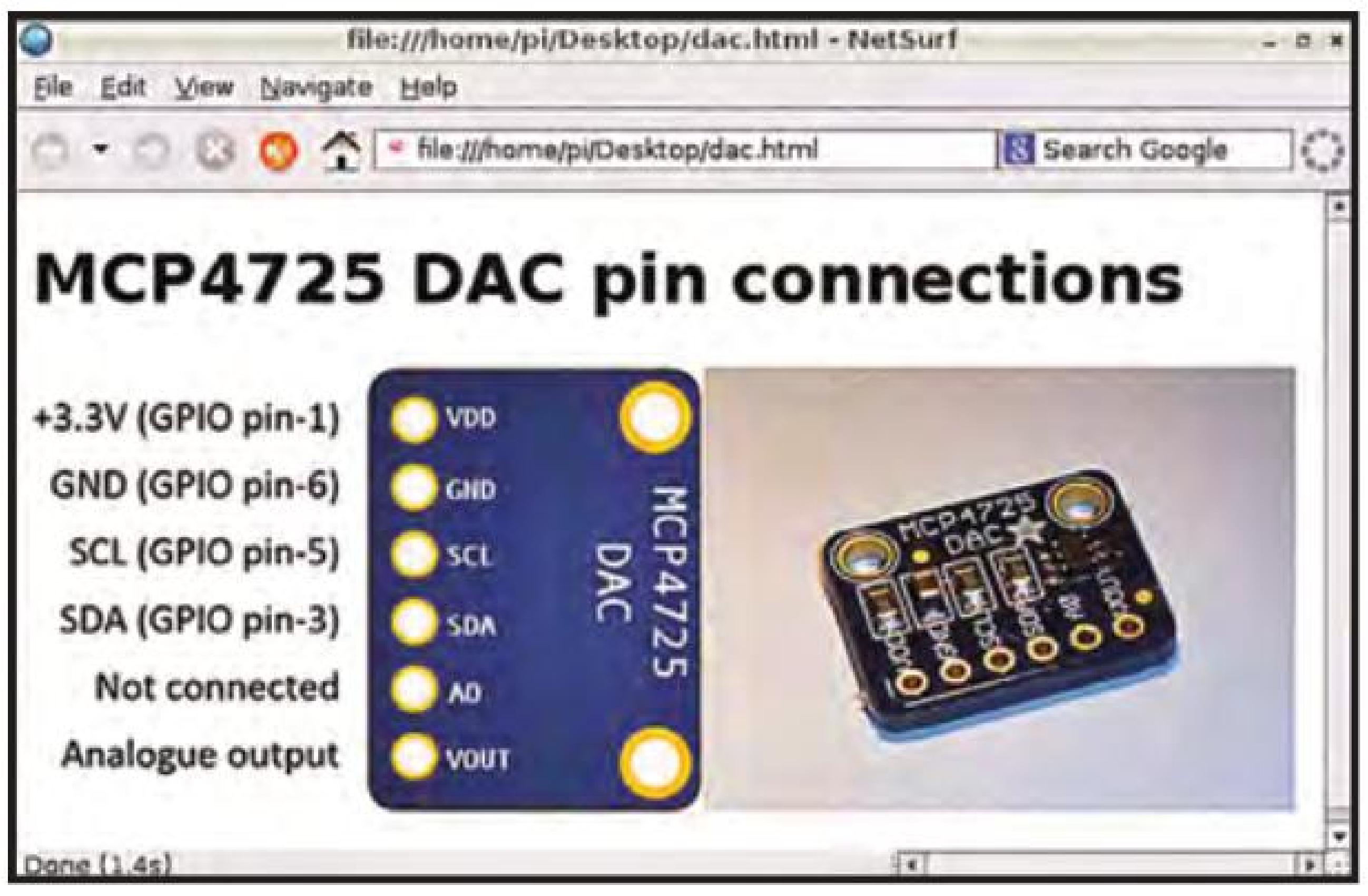
We briefly mentioned earlier that there are other methods of generating the strings that will be used to make up our HTML file. We will bring this month's Python Quickstart to a conclusion by providing you with an example of using Python's `with` statement to tidy up your code.

The `with` statement is often used together with `file.write()` to open, write data and then close a file in one simple block of nested code. Note that the `with` statement will automatically close the file after the nested block of code. The advantage of using the `with` statement is that it is guaranteed to close the file regardless of what happens when the nested code is executed. If an exception does occur before the end of the nested block, the file will be automatically closed. The following code produces exactly the same output as before, but – as you can see – it's a lot more concise!

```
# Import the libraries
import webbrowser
import time

now = time.time()

with open('time.html', 'w') as myFile:
  myFile.write('<html><head></head><body><h2>')
    myFile.write('Time now: ')
    myFile.write(time.ctime(now))
    myFile.write('</h2></body></html>')

# Open the web browser and display the file
webbrowser.open("time.html")
```

Images and graphical content

Images can be easily displayed in an HTML page, as the following example shows. This program writes an HTML file that includes two images. One of these images is a GIF (graphics interchange file) and the other is a PNG (portable network graphics file). Notice how we've opened the web browser object in order to render and display the file that we've created. The result of executing this code is shown in Fig.9.1.


file:///home/pi/Desktop/dac.html - NetSurf
File Edit View Navigate Help
file:///home/pi/Desktop/dac.html
Search Google
VDD
GND
SCL
SDA
A0
VOUT
MCP4725 DAC
Done (1.4s)

MCP4725 DAC pin connections

+3.3V (GPIO pin-1)
GND (GPIO pin-6)
SCL (GPIO pin-5)
SDA (GPIO pin-3)
Not connected
Analogue output

Fig.9.1. Text, GIF and PNG images displayed in an HTML page created by Python

```
# Import the library
import webbrowser

# HTML code to be rendered
html_str = """
<html>
<head>
</head>
<body>
<h1>MCP4725 DAC pin connections</h1>
<img src="fig1.gif"></img>
<img src="fig2.png"></img>
</body>
</html>
"""

# Write the html to a file
file = open("dac.html","w")
file.write(html_str)
file.close()

# Open the web browser and display the file
webbrowser.open("dac.html")
```

Pi Project

Last month, we described the construction of a stepper motor interface based on the versatile NJM2671 stepper motor controller chip. This month, we will be showing you how to build an infrared camera with an integrated light source that's ideal for use with the Raspberry Pi in a wide range of applications, ranging from simple home security to capturing night-time wild life activity. The unit will work in total darkness and is small enough to be tucked away inconspicuously in a hall or passageway, or fitted in a nest box or close by the entrance to an animal's den or lair.

NoIR camera

The Raspberry Pi's NoIR camera is very similar to the standard Raspberry Pi camera module that we met last month. The only significant difference is that the Raspberry Pi NoIR camera has no infrared filter. This makes it ideal for infrared photography as well as for photographing objects in low and very low light conditions. As with the standard Raspberry Pi camera, the NoIR camera module is connected directly to the Raspberry Pi's CSI connector (see Part 8 of *Teach-In 2014* for more information). The NoIR camera is capable of delivering still images of up to 5MP resolution (ie, still pictures of up to 2592 × 1944 pixels) or 1080p HD video recording at 30 frames per second.

The IR camera/lighting module

The simplified block schematic arrangement of the camera/lighting module is shown in Fig.9.2. Two separate light sources are available; one for infrared light and the other for white light. Each of these sources use high-efficiency LED emitters (six in the IR light source and five in the white light source). The emitters (which need an appreciable current) must be supplied from a suitably rated external supply of between 5V and 12V at up to 500mA. A low-cost AC mains power adapter rated at 1A or more is ideal. The two light sources can be independently controlled so that it is possible to select no lighting, IR lighting only, white lighting only and both IR and white light at the same time. This adds considerably to the versatility of the camera/lighting module and improves picture quality when there is no need for the camera lighting source to remain invisible to the human (or animal) eye. Note that the NoIR camera derives its DC supply directly from the Raspberry Pi via the CSI connector.

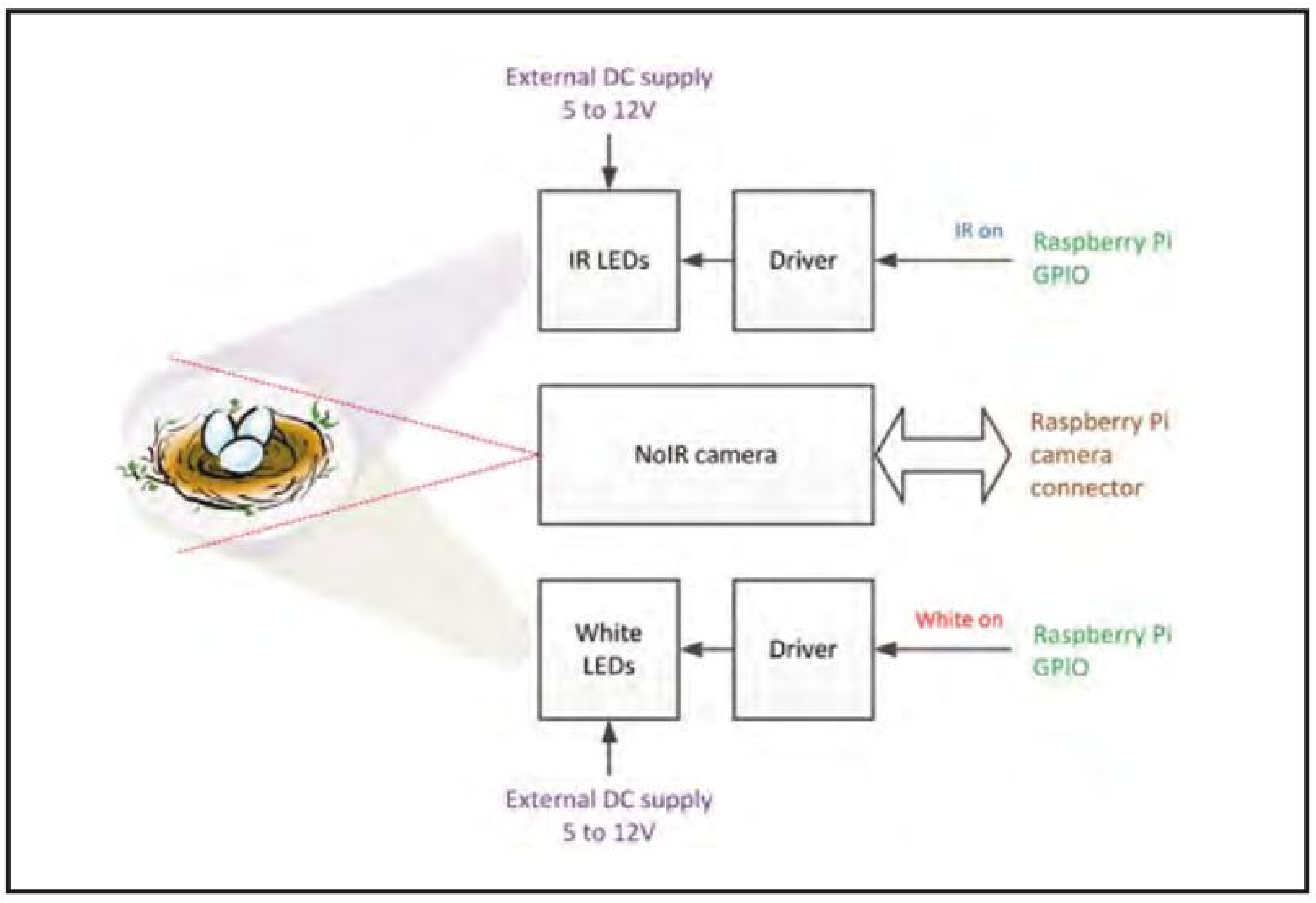

External DC supply
5 to 12V
IR LEDs
Driver
IR on
Raspberry Pi GPIO
NoIR camera
Raspberry Pi camera connector
White LEDs
Driver
White on
Raspberry Pi GPIO
External DC supply
5 to 12V

Fig.9.2. Simplified block schematic arrangement of the camera/lighting module

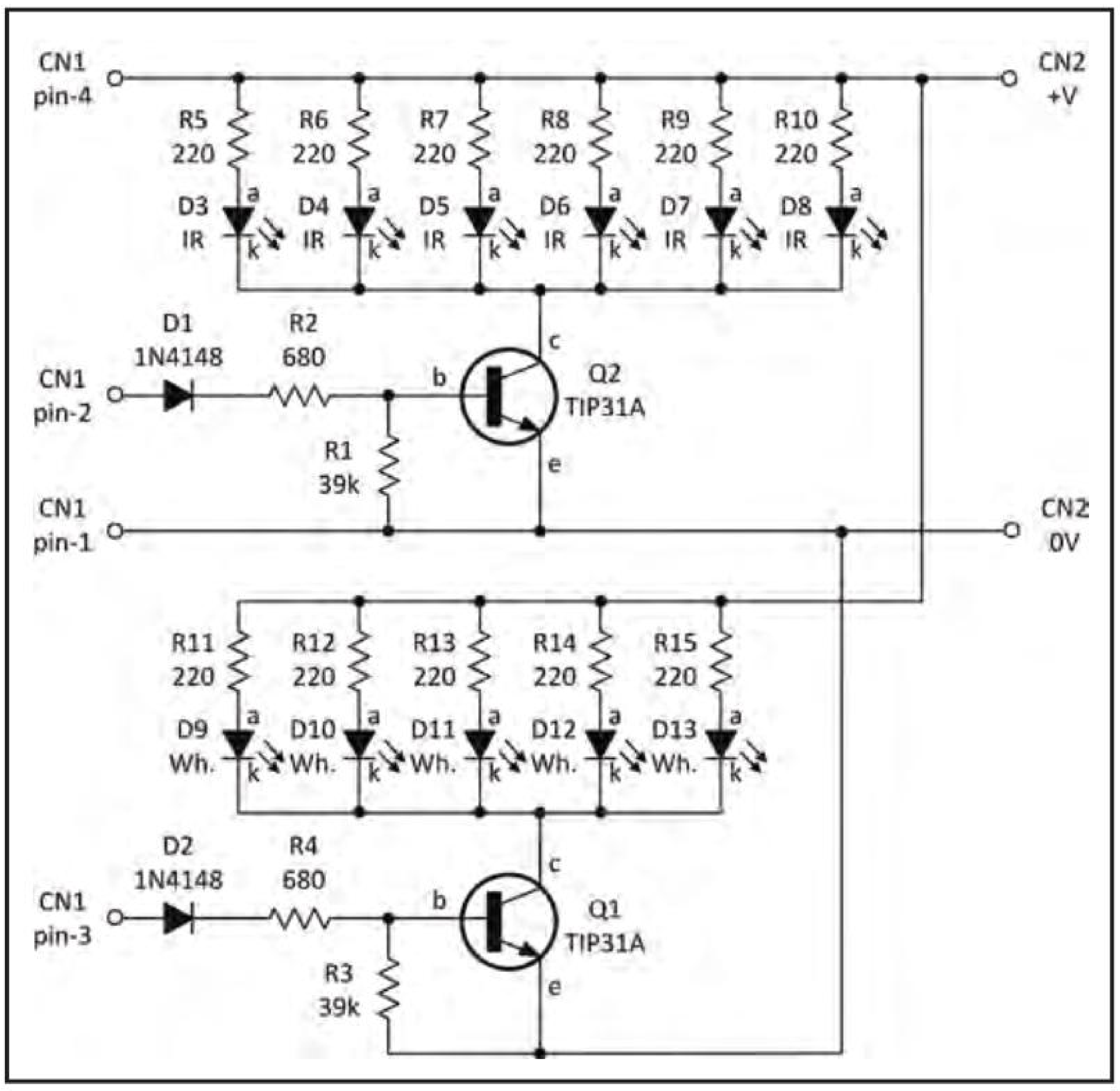

CN1 pin-4
CN2 +V
R5 220
R6 220
R7 220
R8 220
R9 220
R10 220
D3 IR
D4 IR
D5 IR
D6 IR
D7 IR
D8 IR
D1 1N4148
R2 680
CN1 pin-2
Q2 TIP31A
R1 39k
CN1 pin-1
CN2 0V
R11 220
R12 220
R13 220
R14 220
R15 220
D9 Wh.
D10 Wh.
D11 Wh.
D12 Wh.
D13 Wh.
D2 1N4148
R4 680
CN1 pin-3
Q1 TIP31A
R3 39k
a
k
b
c
e

Fig.9.3. Circuit of the camera lighting unit

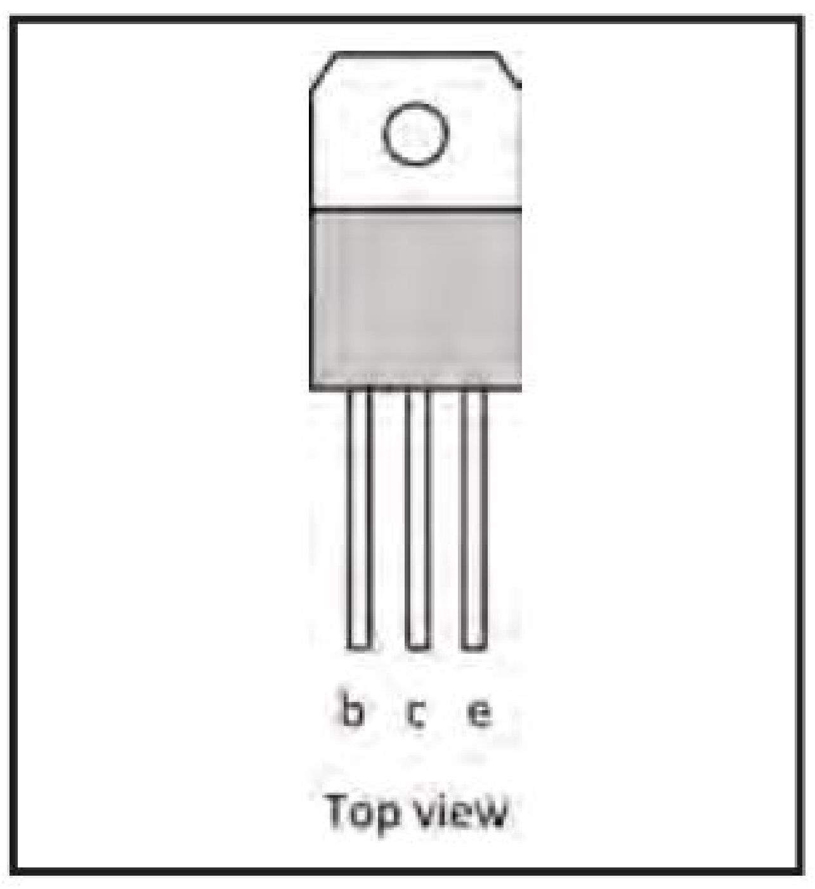

b c e
Top view

Fig.9.4. Pin connections for Q1 and Q2

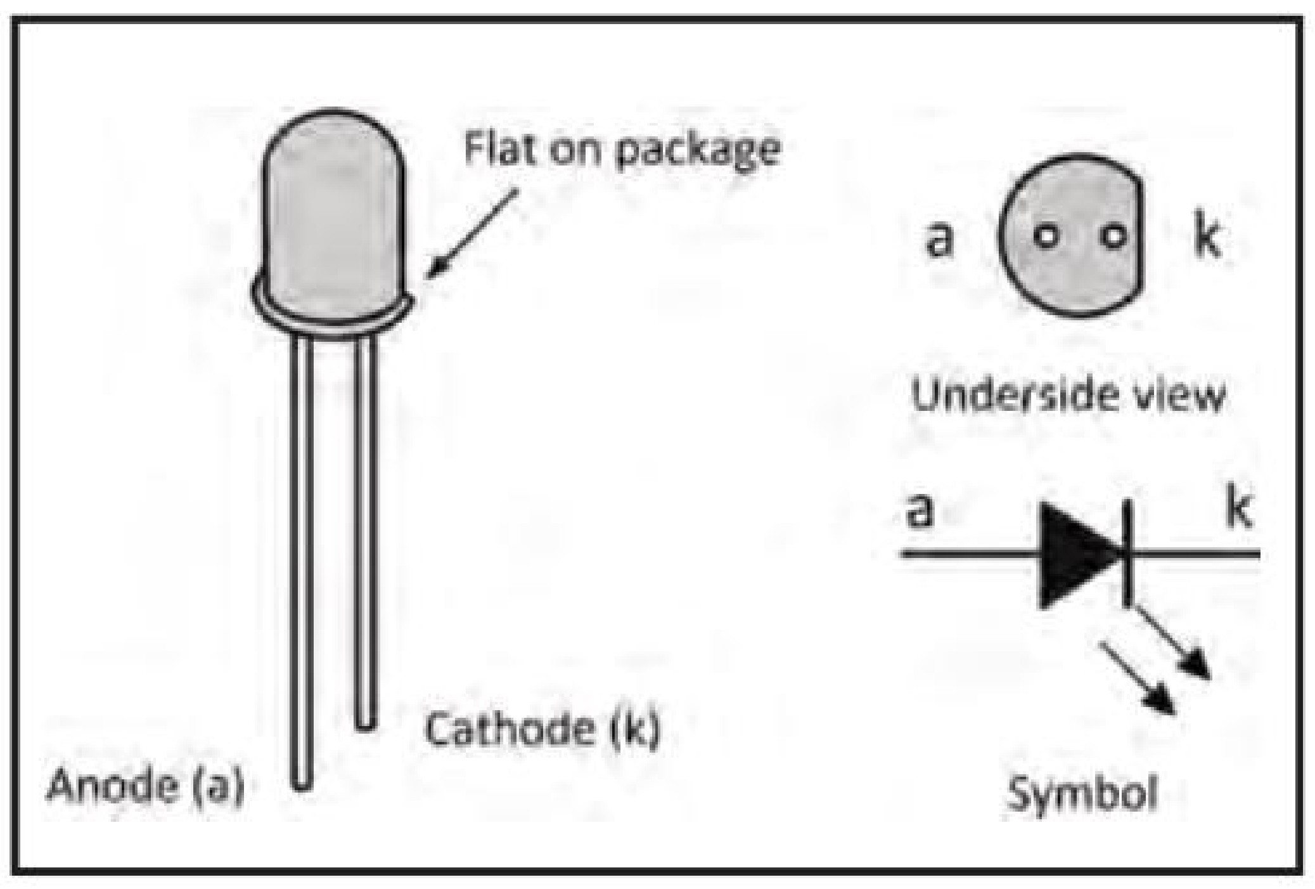

Flat on package
a
k
Underside view
a
k
Anode (a)
Cathode (k)
Symbol

Fig.9.5 Pin connections for D3 to D13

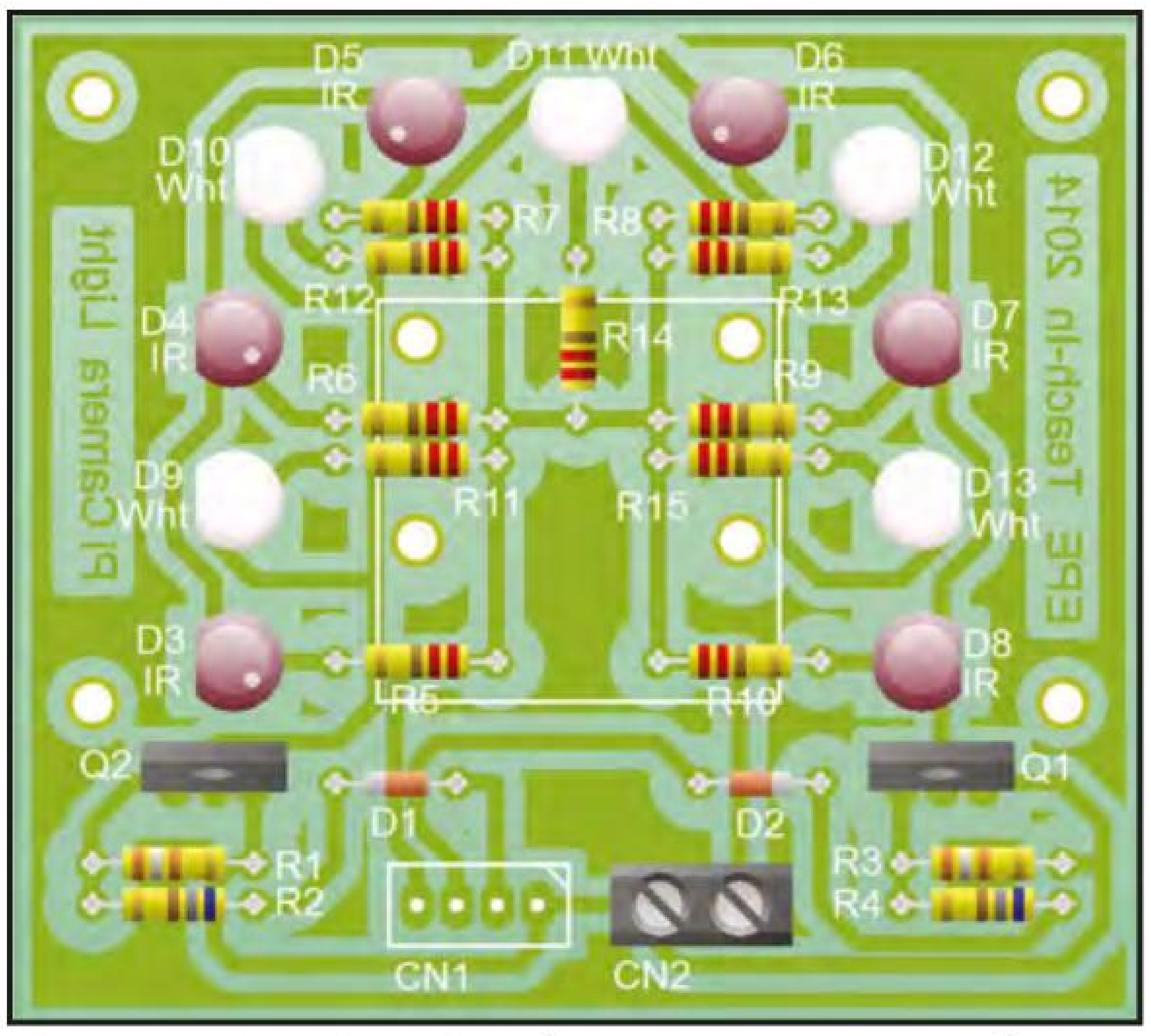


Fig.9.6. Circuit Wizard PCB component layout for the camera lighting unit

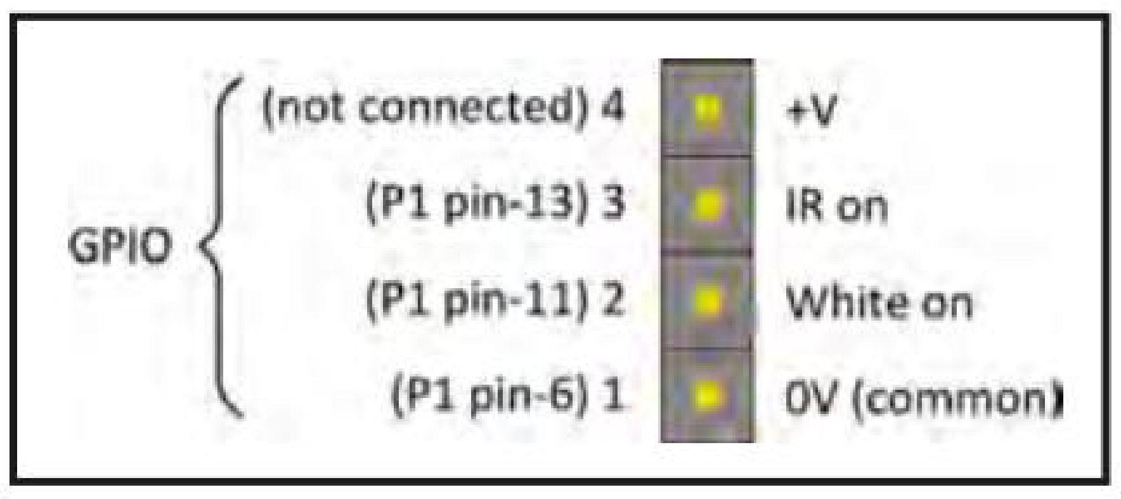


Fig.9.7. Connections to CN1

The circuit diagram of the IR and white light source is shown in Fig.9.3. Two low-cost TO220 silicon power transistors, Q1 and Q2, are used as drivers (saturated switches) to control the current through the LEDs. These transistors need no additional heat sinking arrangements. The pin connections for Q1 and Q2 are shown in Fig.9.4, while the pin connections for the LEDs are shown in Fig.9.5.

The camera/lighting module is assembled using a small printed circuit board measuring approximately 64mm × 72mm. We used Circuit Wizard to design the printed circuit board layout shown in Fig.9.6. Detailed information on using Circuit Wizard can be found in our earlier *Jump Start* series, which has been published in *Electronics Teach In 5* (available from *EPE Book Service*, see page 68). The printed circuit board is available from the *EPE PCB Service* (order code 905).

The camera/lighting module requires two signal connections and 0V (common) from the Raspberry Pi's GPIO (marked P1 on the Raspberry Pi's PCB). These connections are shown in Fig.9.7 (note that pin-4 is only used for test purposes and *must not* be connected to the Raspberry Pi). In addition, a flexible cable is needed to connect the camera board directly to the Raspberry Pi's CSI connector (see Fig.8.24 to 8.26 of *Teach-In 2014*, Part 8).

The fully populated camera/lighting PCB is shown in Fig.9.8. The infrared and white LEDs are mounted alternately in a circle that has its centre at the centre of the PCB where the camera board is fitted. The camera board is fitted as a 'daughter board' above the main PCB and attached using four (very) small screws and insulated mounting pillars, as shown in Fig.9.9 and Fig,9.10.

Choice of light emitters and series resistors

A variety of different types of infrared and white LED emitters can be fitted to the module. For the infrared lighting we decided to use Vishay TSAL6100 IR emitters (available from CPC order code SC12368) which provide peak output at 950nm with a maximum forward current of 100mA and a forward voltage of 1.35V. These devices provide a reasonably high amount of illumination at low cost.

For the white lighting we used Kingbright L-7113QWC-D (CPC order code SC08786). These LEDs provide an output of up to 1200mcd and are rated for a maximum forward current of 30mA with a forward voltage 3.3V. Other, more expensive versions of the

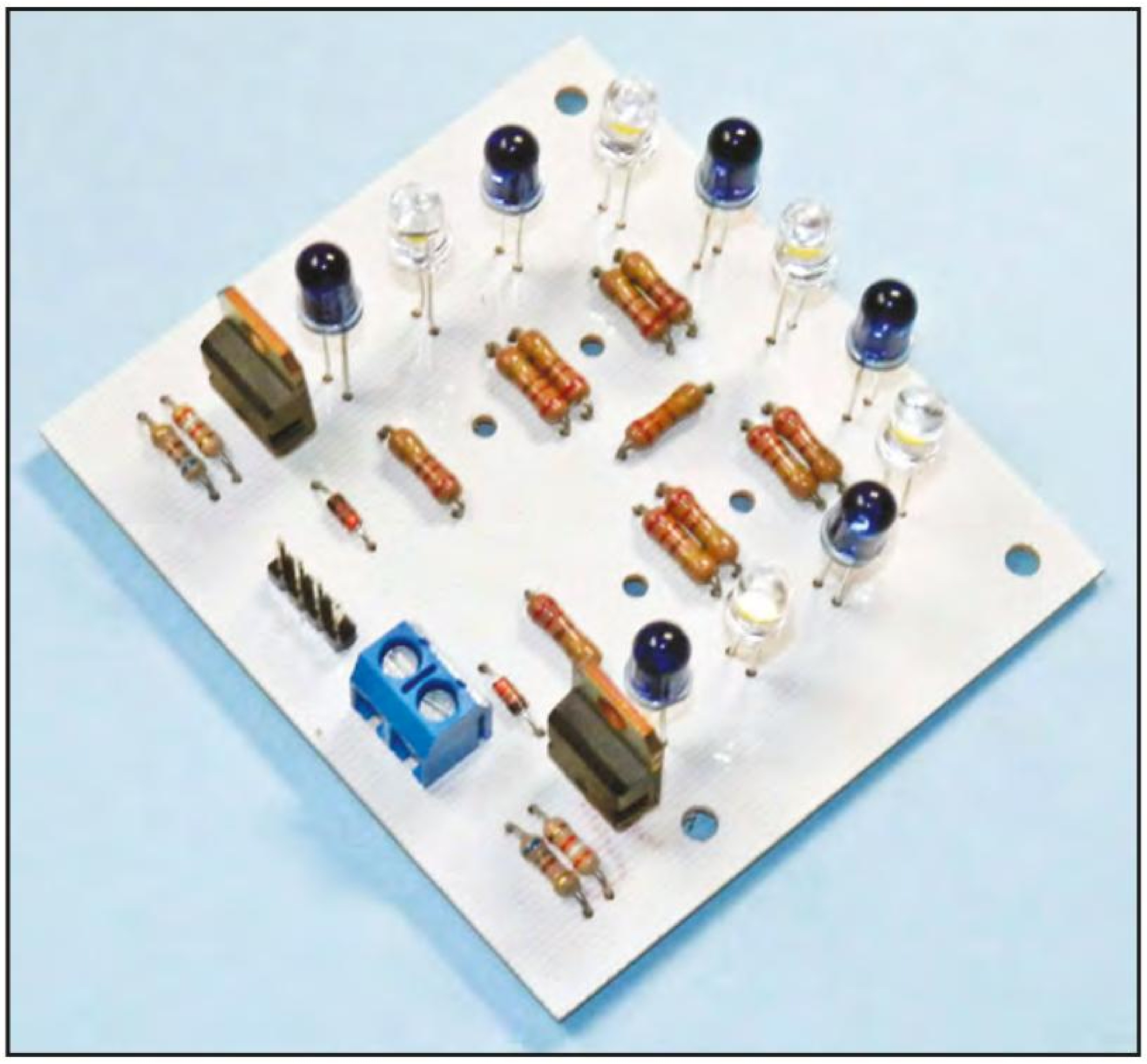


Fig.9.8. Completed PCB ready for the NoIR camera module

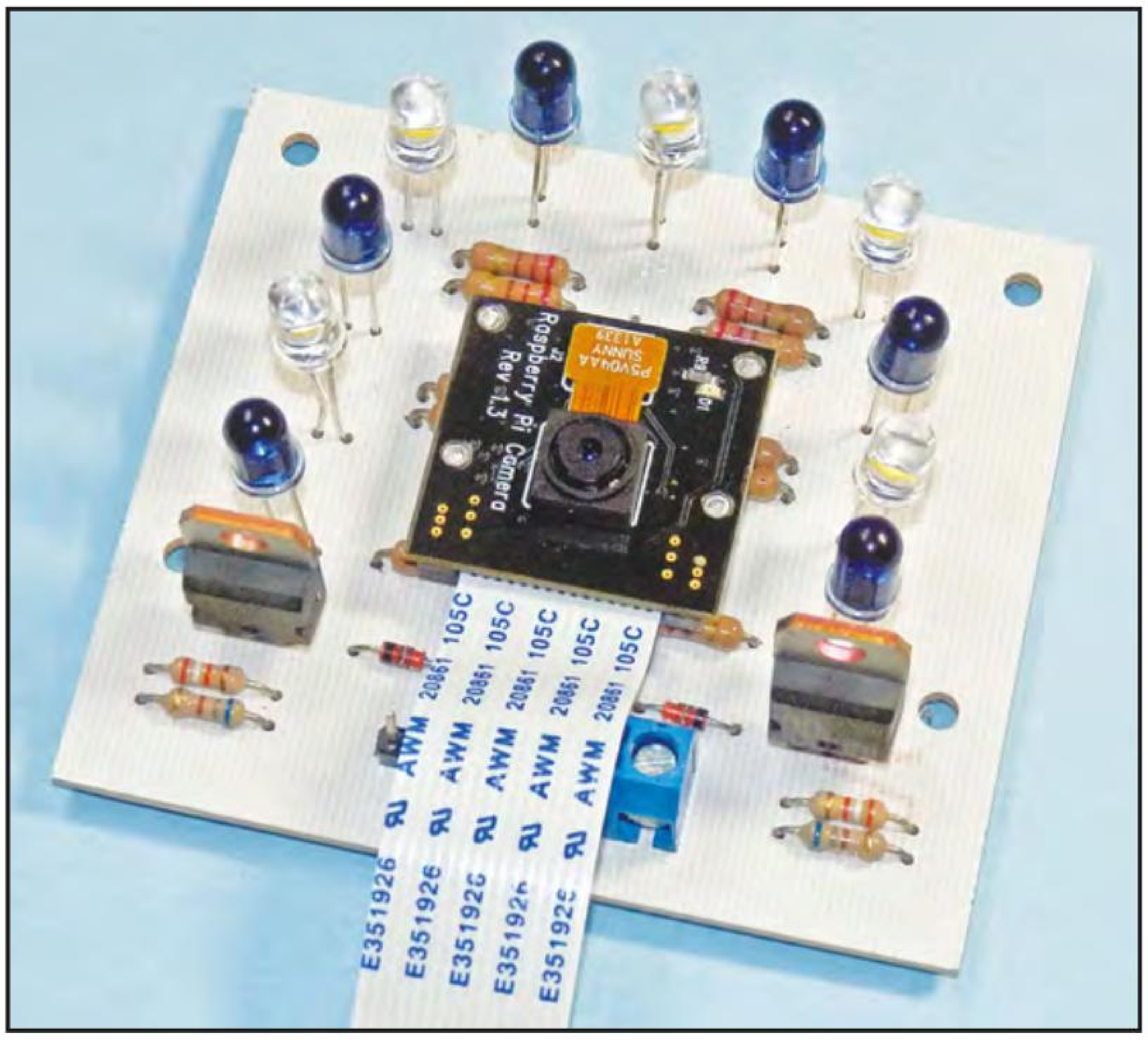


Fig.9.9. PCB with camera module and flexible connector

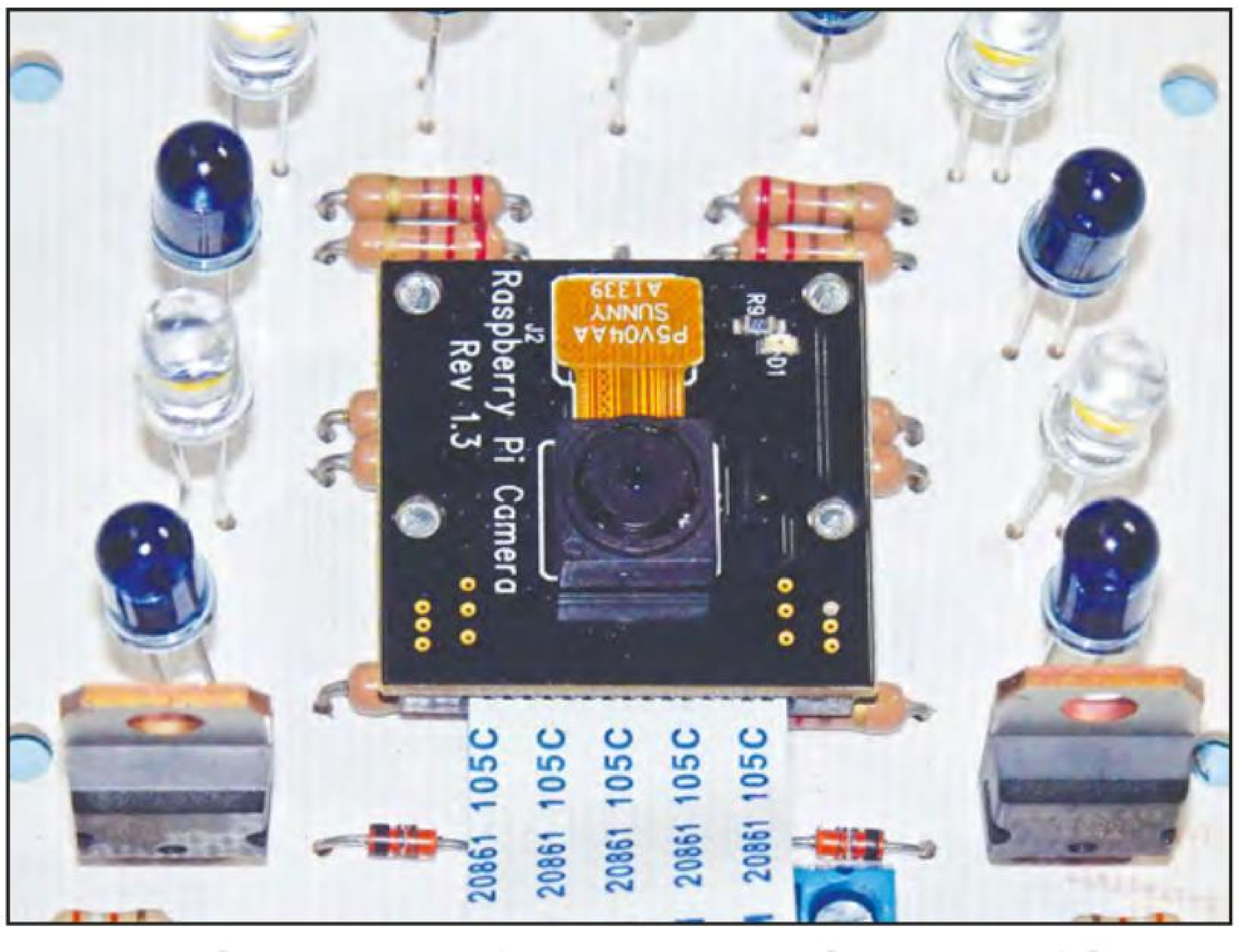


Fig.9.10. Close-up view of camera mounted in centre of the PCB

Table 9.1 Recommended values for R5 to R10 (approx. 40mA per IR emitter)

Supply voltage (V)	Resistance (Ω)	Power (W)
5	100	0.25
6	120	0.25
7.5	150	0.3
9	180	0.5
12	270	0.5

Table 9.2 Recommended values for R11 to R15 (approx. 20mA per white emitter)

Supply voltage (V)	Resistance (Ω)	Power (W)
5	100	0.25
6	150	0.25
7.5	220	0.25
9	270	0.25
12	390	0.25

Kingbright L-7113QWC emitter can be used for applications that require more light output. For example, the L-7113QWC-G provides an output of up to 8000mcd but at about four times the price of the cheaper version (and don't forget that you will need six of them).

Series resistors, R5 to R10, are used to limit the current supplied to the IR emitters, D3 to D8 respectively. Likewise, resistors, R11 to R10, are used to limit the current supplied to the white emitters, D9 to D13 respectively. The choice of resistance value will determine the current supplied to the respective light source, but must also be chosen with the DC supply voltage in mind. For test purposes, we fitted 220Ω resistors for R5 to R10 and operated our prototype from a 5V DC supply rated at 500mA. The recommended resistor values for different supply voltages are shown in Table 9.1 and Table 9.2 for the IR and white emitters, respectively.

The maximum and minimum values of series resistor for the IR and white emitters (specified earlier) are shown in Table 9.3. Note also that in situations where the total current (see Table 9.3) exceeds 300mA it is advisable to reduce the values of R1 and R2 to 330Ω in order to ensure that Q1 and Q2 operate under fully saturated conditions.

Infrared light and IR emitters

Infrared (IR) light usually has a wavelength of between 840nm and 850nm and is barely visible to the human eye. Because of this, it is an ideal way of illuminating a subject in darkness and low-light levels without causing light pollution and annoyance, and also without the subject being aware of it. However, when used with a special infrared sensitive camera, the light can appear very bright and images can be almost as clear as those that can be achieved in normal daylight.

Light-emitting diodes (LEDs) are solid-state P-N junction devices that emit light when forward biased. Unlike incandescent lamps that emit light over a wide range of wavelengths, LEDs emit light over such a narrow bandwidth that they appear to be emitting only a single colour, such as red, yellow or green. IR emitters are a sub-family of LEDs that emit light at a wavelength that is just beyond the normal visible range They are simple and easy to use and only require very modest amounts of power.

A standard red LED produces light at a wavelength of about 630nm, while infrared LEDs operate at between 840nm and 950nm, with the longer wavelengths being less visible to the human eye as they are further away from the visible spectrum.

Table 9.3 Recommended maximum and minimum series resistances

Nominal supply voltage		5V		6V		7.5V		9V		12V	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
IR	R5 to R10	100	220	100	220	120	330	150	470	220	560
	I_f (per LED)	36	16	46	21	51	18	51	16	48	19
White	R11 to R15	100	220	120	270	180	390	270	470	390	680
	I_f (per LED)	17	12	23	10	23	11	21	12	22	13
Approx. total supply current		300	160	390	180	420	160	410	160	400	180

Home Baking

In this month's *Home Baking* we will be developing some Python code that we can use to operate the camera/lighting module described in this month's *Pi Project*. The software needs to be able to operate each of the light sources independently, either from commands entered via the standard Python command line interface or (preferably) using some form of graphical user interface. We shall look at each of these two different approaches in turn, but first, and before we do anything else, we need to remember to configure the GPIO port.

Configuring the GPIO

First we need to install the GPIO library and then set the mode to be used when referring to the GPIO connections. Here's a block of code that will do this using the Raspberry Pi's own board pin numbering scheme:

```
# Import the GPIO library module
import RPi.GPIO as GPIO

# Set the GPIO pin numbering convention
GPIO.setmode(GPIO.BOARD)

# Configure the GPIO
GPIO.setmode(GPIO.BOARD)
GPIO.setup(11, GPIO.OUT)  # White LEDs
GPIO.setup(13, GPIO.OUT)  # IR LEDs
```

Next we need to be able to switch the two light sources on and off.

Switching the light emitters on and off

Switching the GPIO output lines on and off couldn't be easier. To keep the code simple and also to make it easier to follow and re-use, we will create some user-defined functions (UDF) that will allow us to control the individual sets of LEDs. The necessary functions are as follows:

```
# To turn the white LEDs on
def white_on():
   GPIO.output(11, True)
# To turn the white LEDs off
def white_off():
   GPIO.output(11, False)

# To turn the IR LEDs on
```

```
def IR_on():
   GPIO.output(13, True)
# To turn the IR LEDs on
def IR_off():
   GPIO.output(13, False)
```

Having defined these four UDFs at the start of our code, we can go on to use them as many times as we need. For example, we might need to ensure that both sets of lights are initially de-activated. Our user-defined functions allow us to do this very easily by simple inserting the following two lines of code before the program's main loop starts:

```
white_off()
IR_off()
```

Now here's some code that will allow you to test the camera/lighting module directly from the Raspberry Pi's Python console:

```
# Import the GPIO library module
import RPi.GPIO as GPIO
import tkinter as tk

# Set the GPIO pin numbering convention
GPIO.setmode(GPIO.BOARD)

# Configure the GPIO
GPIO.setmode(GPIO.BOARD)
GPIO.setup(11, GPIO.OUT) # White LEDs
GPIO.setup(13, GPIO.OUT)  # IR LEDs

# User-defined functions
def white_on():
  GPIO.output(11, True)
def white_off():
  GPIO.output(11, False)
def IR_on():
  GPIO.output(13, True)
def IR_off():
  GPIO.output(13, False)

# Initialise with both sets of LEDs off
white_off()
IR_off()

# Print key selection
print("Camera lighting controller")
print("========================")
print("[W] white on, [S] white off,
[R] IR on, [F] IR off, [Q] to quit")

# Respond to a key press
while True:
   x = ""
    x = input("Enter command letter
: ")
    if x == "q":
      print("Program terminated")
      break
    elif x == "w":
      print("White ON")
      white_on()
    elif x == "s":
      print("White OFF")
      white_off()
    elif x == "r":
      print("Infra red ON")
      IR_on()
    elif x == "f":
      print("Infra red OFF")
      IR_off()
```

The last program is functional, but unfortunately it doesn't look very professional. A better and much more user-friendly approach would be to build a simple graphical user interface based on tkinter. Since we have four different possibilities for our lighting (no lighting, IR lighting only, white lighting only and both IR and white light simultaneously) we could simply make use of two check buttons, one to turn the IR emitters on and off and one to turn the white emitters on and off (see Fig.9.11).

Here's some code that uses tkinter to produce the much more professional looking GUI interface that's being tested in Fig.9.12.

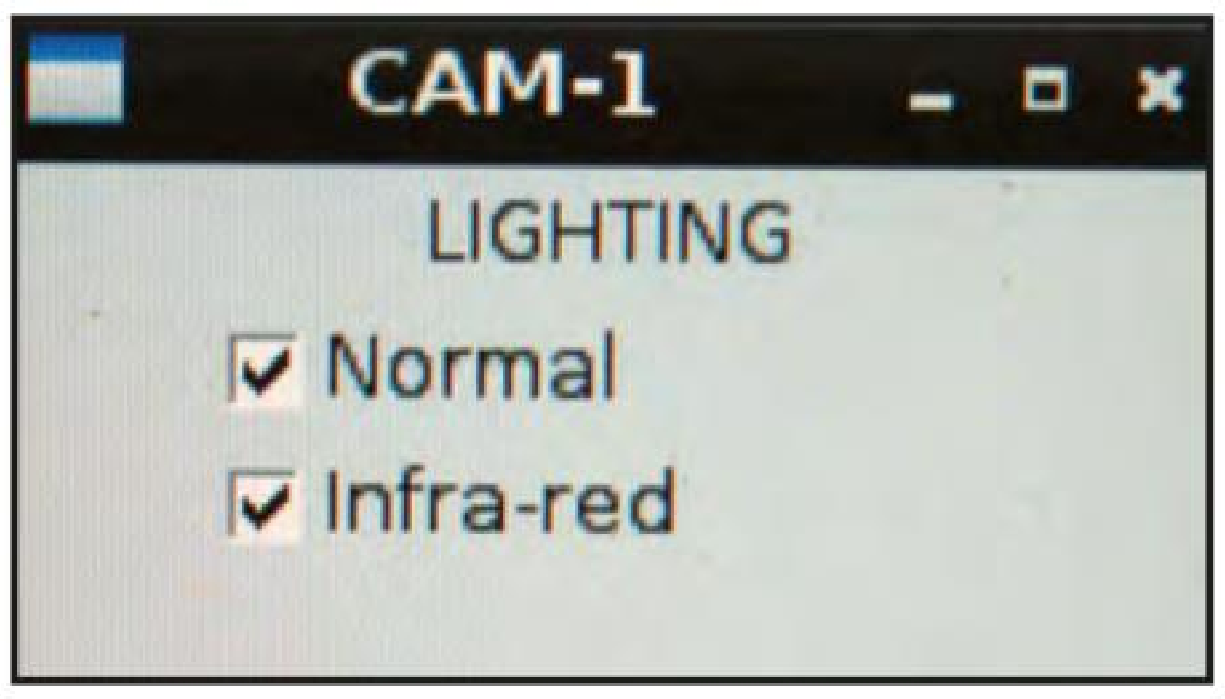
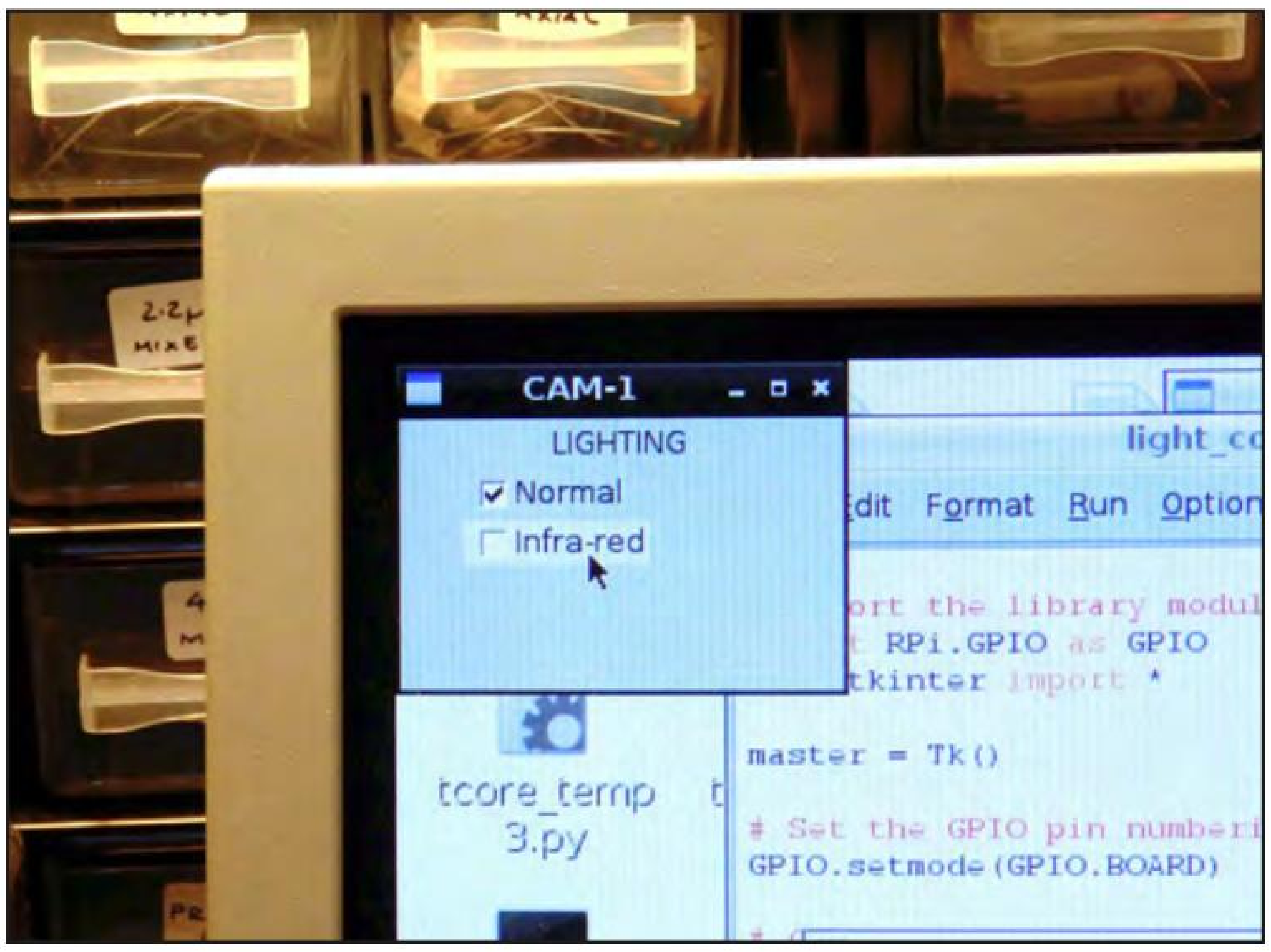


Fig.9.11. The GUI dialogue box with check boxes

```
# Import the library modules
import RPi.GPIO as GPIO
from tkinter import *

master = Tk()

# Set the GPIO pin numbering
convention
GPIO.setmode(GPIO.BOARD)

# Configure the GPIO
GPIO.setmode(GPIO.BOARD)
GPIO.setup(11, GPIO.OUT)  # White LEDs
GPIO.setup(13, GPIO.OUT)  # IR LEDs

# User-defined functions
def white_on():
  GPIO.output(11, True)
def white_off():
  GPIO.output(11, False)
def IR_on():
  GPIO.output(13, True)
def IR_off():
  GPIO.output(13, False)

# User-defined functions to handle checkbutton events
def go():
    print("OK clicked")

def normal():
    if w.get()==1:
        print("White on")
        white_on()
    else:
        print("White off")
        white_off()
def infrared():
    if x.get()==1:
        print("IR on")
        IR_on()
    else:
        IR_off()
        print("IR off")

# Set up window size and title
master.geometry("%dx%d%+d%+d" % (180, 110, 0, 0))
master.wm_title("CAM-1")

w = IntVar() # Normal checkbutton state
x = IntVar() # Infra-red checkbutton state

# Initialise with both sets of LEDs off
white_off()
IR_off()
print("White off")
print("IR off")

# Place a message and checkbuttons in the window
Message(master, text="LIGHTING", width=150).pack(padx=25,
anchor=CENTER)
Checkbutton(master, text="Normal", variable=w,
command=normal).pack(padx=25, anchor=NW)
Checkbutton(master, text="Infra-red", variable=x,
command=infrared).pack(padx=25, anchor=NW)

master.mainloop()
```



```
ort the library modul
t RPi.GPIO as GPIO
tkinter import *

master = Tk()

# Set the GPIO pin numberi
GPIO.setmode(GPIO.BOARD)
```

Fig.9.12. Testing the dialogue box

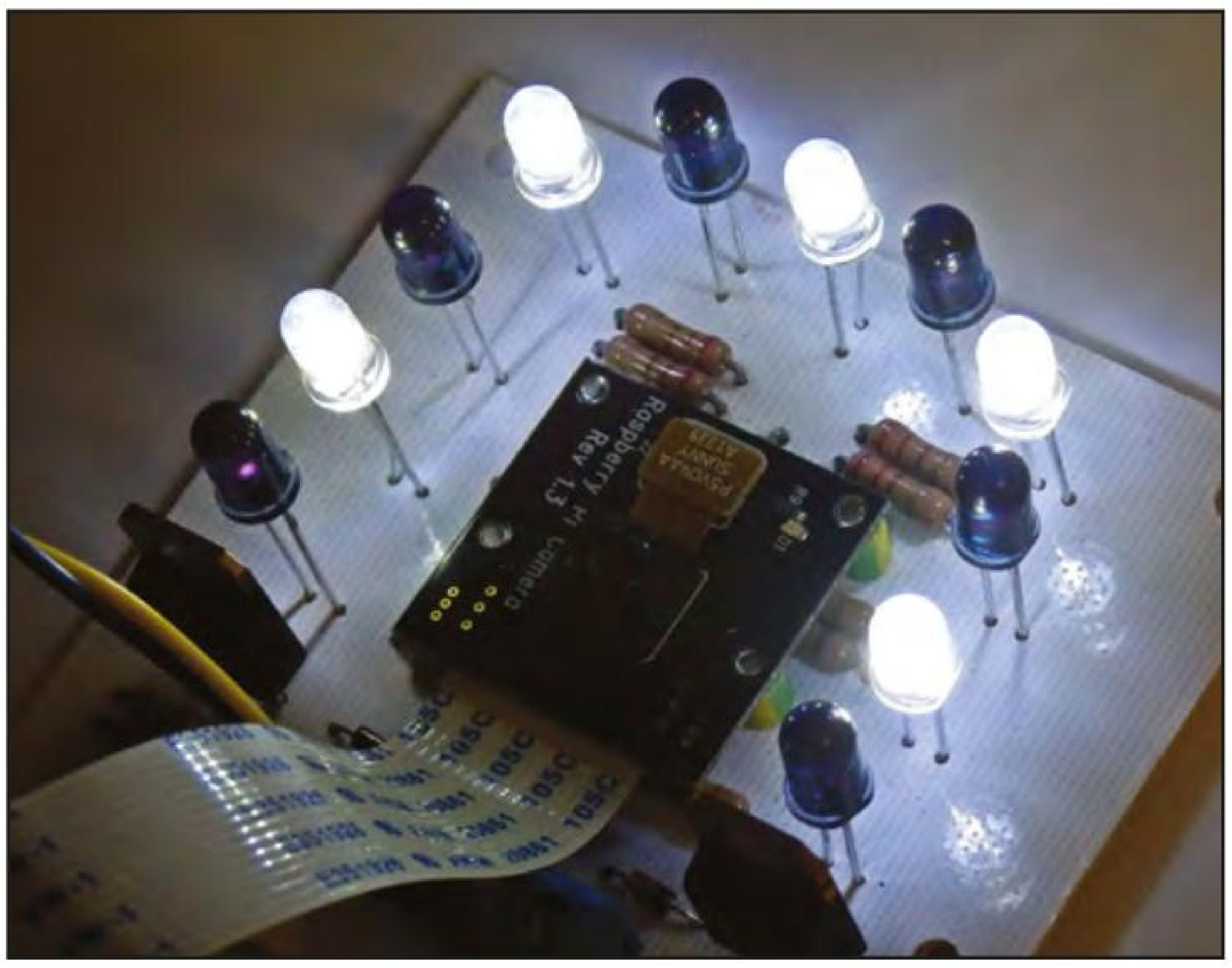


Fig.9.13. Testing the prototype camera/lighting module with the Normal checkbox ticked

The result of clicking on the GUI interface's 'Normal' check button with each of the white emitters producing light is shown in Fig.9.13. Finally, Fig.9.14 provides you with a comparison of camera performance with an image taken in almost total darkness and with minimal light output from both the IR and white emitters. To take these images we operated the camera/lighting module from a 5V DC supply (rated at 500mA) and used with a relatively large value of resistance (220Ω) for all the series resistors, R5 to R15. In practice, a much greater amount of illumination would have been provided with the use of a 7.5V supply (see Table 9.3).

Pi World

In our occasional *Pi World* series, we aim to introduce you to a wide range of Raspberry Pi accessories, including ready-made I/O boards, prototype cards, bus extenders and other adapters. This month we take a look at a versatile yet inexpensive I/O adapter.

Introducing Custard Pi 2

Custard Pi 2 (see Fig.9.15) is one of a series of Raspberry Pi I/O modules available from SF Innovations (**www.sf-innovations.co.uk**). This inexpensive and versatile board provides you with a range of analogue and digital I/O for your Raspberry Pi. The available I/O comprises:

- Four open-collector digital outputs (ideal for LEDs and relays)
- Four buffered digital inputs (ideal for switches / digital sensors)
- Two 12-bit analogue outputs
- Two 12-bit analogue inputs.

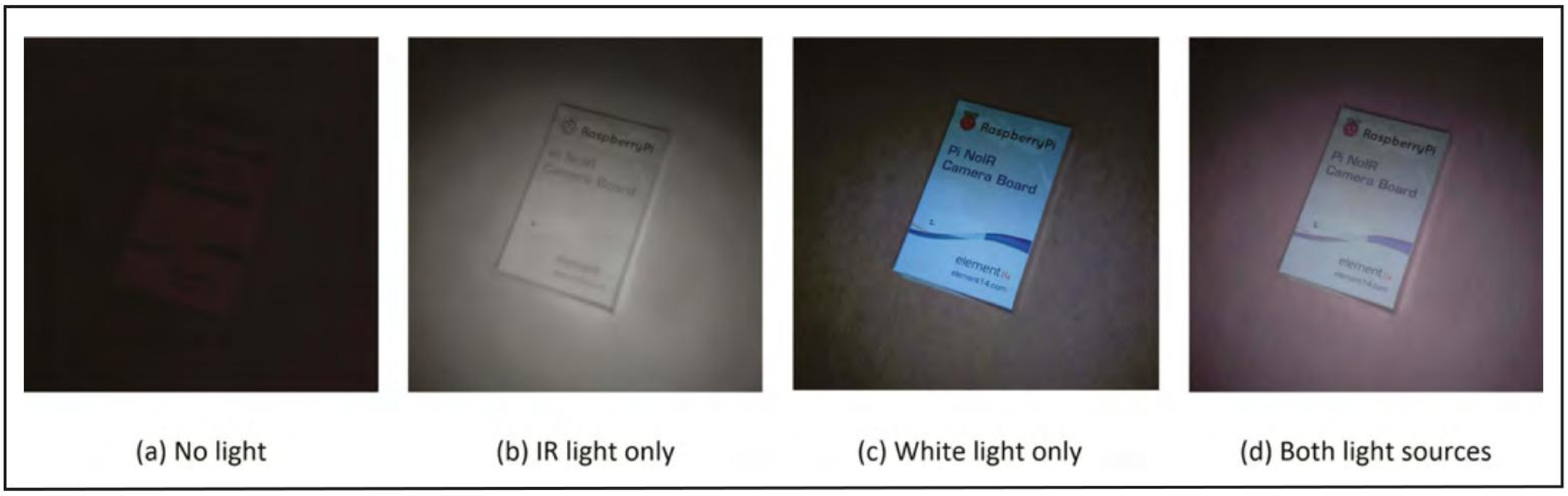
The four digital I/O connections can be taken to a maximum of 50V in the high-state and each can sink a current of up to 500mA when driven low. This makes the Custard Pi 2 ideal for use with a wide range of loads, including relays, small motors and actuators.

All of the Custard Pi 2's I/O is available from a printed circuit board that's actually smaller than the Raspberry Pi itself and, like many other proprietary I/O boards, it fits neatly over the Raspberry Pi motherboard. The Custard Pi 2 makes its connection to the Pi using the 26-way GPIO header and all of the inputs and outputs are made available by screw terminals. Two LEDs are fitted to the board in order to indicate the presence of the +3.3V and +5V power supplies, and all of the pins on the Pi are protected from accidental connection of a high voltage. A further useful feature is that both the +3.3V and +5V voltage rails have 100mA multi-fuses fitted.

The I/O schematic and printed circuit board layout of the Custard Pi 2 is shown respectively in Figs.9.16 and 9.17. The Custard Pi 2 uses a ULN2801A eight-bit Darlington transistor array for its digital I/O. An MPC4822 provides 12-bit digital-to-analogue conversion (DAC) for the Custard Pi 2's analogue output and an MCP3202 provides 12-bit analogue-to-digital conversion (ADC) for its analogue input. Both of these chips provide two independent channels. The interface to the Raspberry Pi for the ADC and DAC chips is based on SPI (see example code on page 43). The digital I/O makes use of the Raspberry Pi's standard GPIO library (see example code on page 43).

Custard Pi 2 digital I/O

The following code initialises all four of the Custard Pi's digital outputs before taking all four of them first low for 10 seconds, then high for 10 seconds and finally back to low:



(a) No light

(b) IR light only

(c) White light only

(d) Both light sources

Fig.9.14. Comparison of camera performance with minimal light output (5V DC supply and 220Ω resistors for R5 to R15

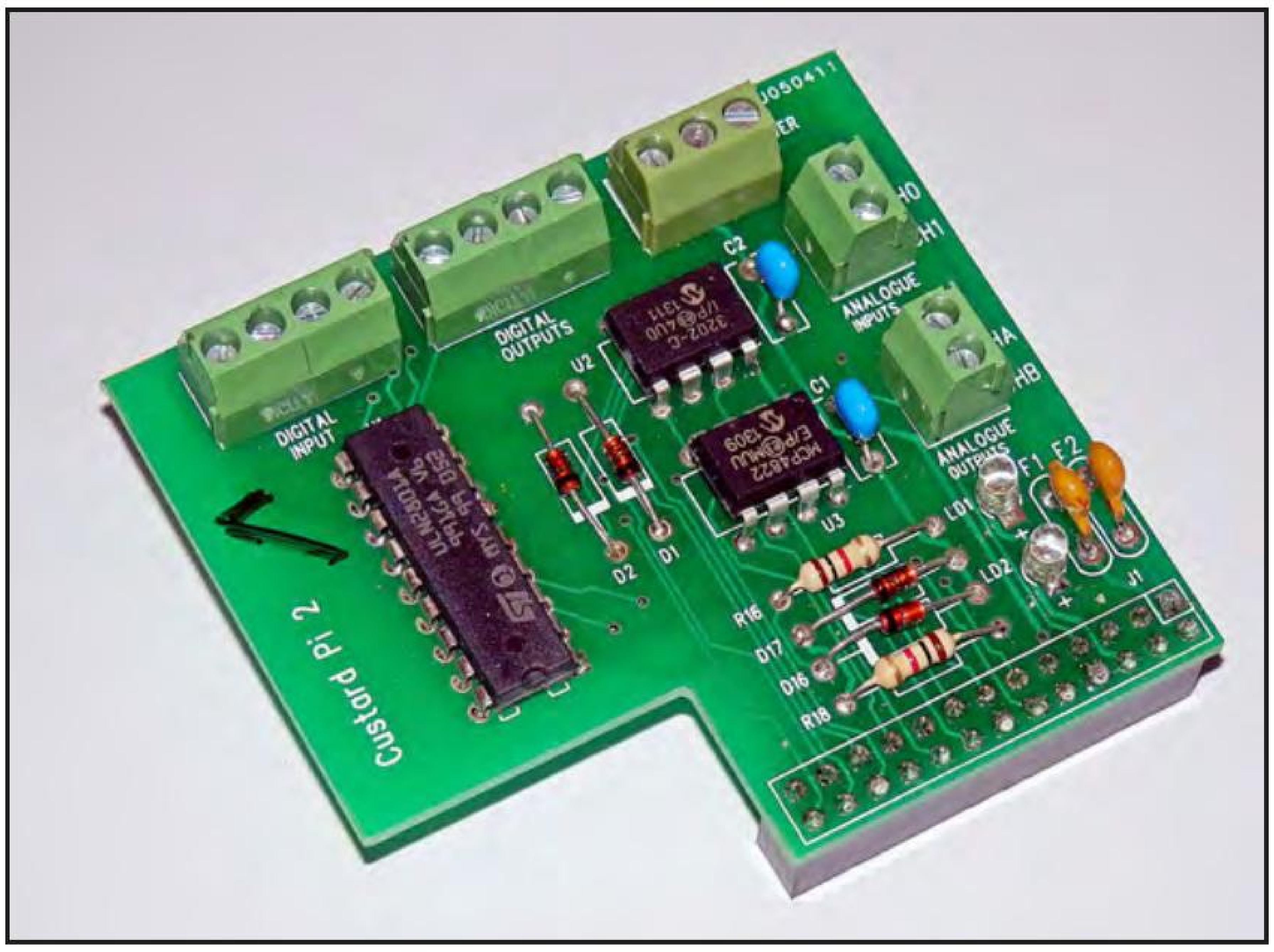


Fig.9.15. The Custard Pi 2 from SF Innovations

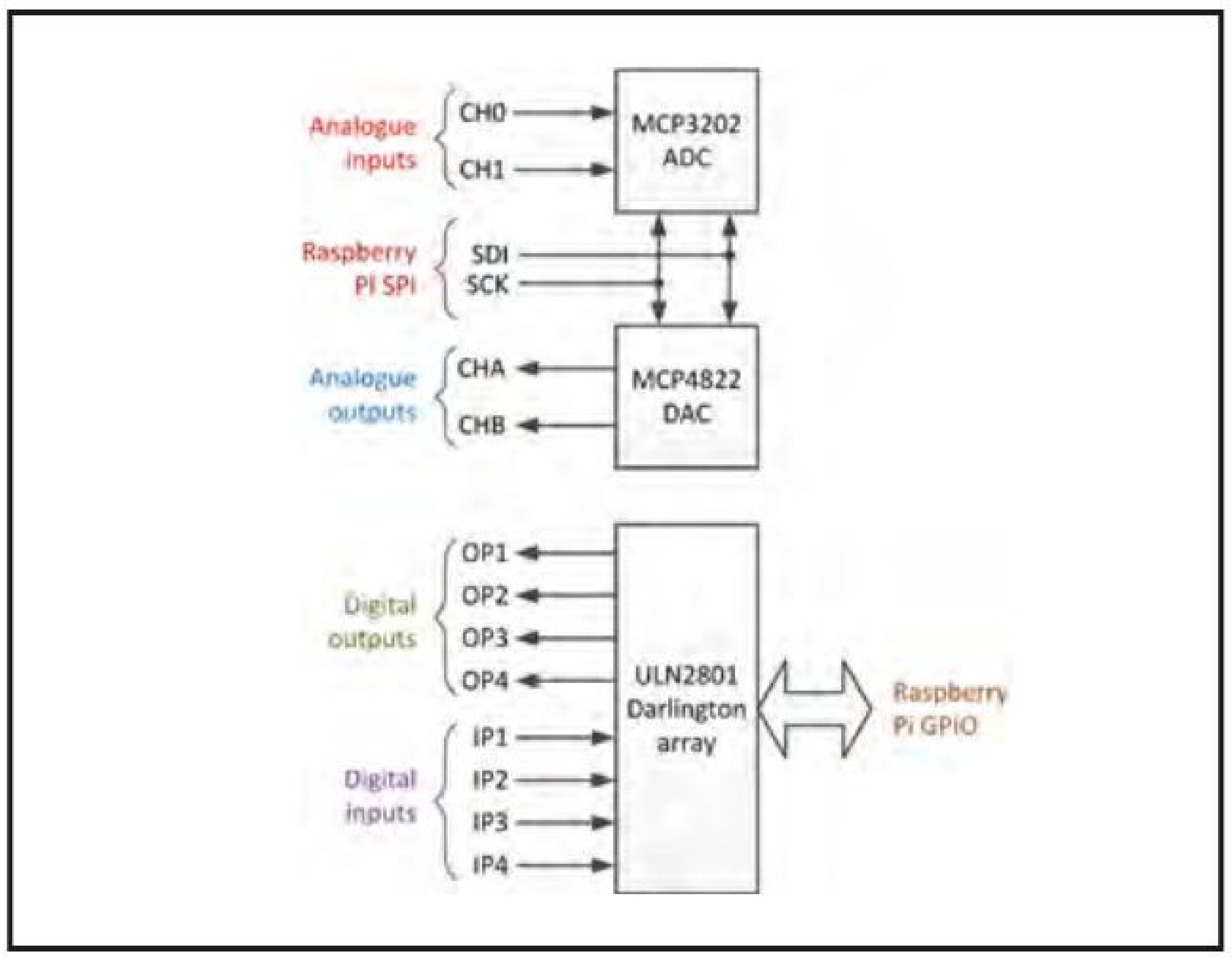

Analogue inputs
CH0
CH1
MCP3202 ADC
Raspberry Pi SPI
SDI
SCK
Analogue outputs
CHA
CHB
MCP4822 DAC
Digital outputs
OP1
OP2
OP3
OP4
ULN2801 Darlington array
Raspberry Pi GPIO
Digital inputs
IP1
IP2
IP3
IP4

Fig.9.16. Custard Pi 2 I/O schematic

```
# Custard Pi 2 digital output

# First we need to import the required library modules
import RPi.GPIO as GPIO
import time

# Set the GPIO pin numbering convention
GPIO.setmode(GPIO.BOARD)

# Set up the required GPIO pins as outputs
GPIO.setup(11, GPIO.OUT)
GPIO.setup(12, GPIO.OUT)
GPIO.setup(13, GPIO.OUT)
GPIO.setup(15, GPIO.OUT)

# Set all outputs low
GPIO.output(11, True)
GPIO.output(12, True)
GPIO.output(13, True)
GPIO.output(15, True)

# Wait 10 seconds
time.sleep(10)

# Set all outputs high
GPIO.output(11, False)
GPIO.output(12, False)
GPIO.output(13, False)
GPIO.output(15, False)

# Wait ten seconds
time.sleep(10)

# Set all outputs low again
GPIO.output(11, True)
GPIO.output(12, True)
GPIO.output(13, True)
GPIO.output(15, True)

# Tidy up
GPIO.cleanup()
```

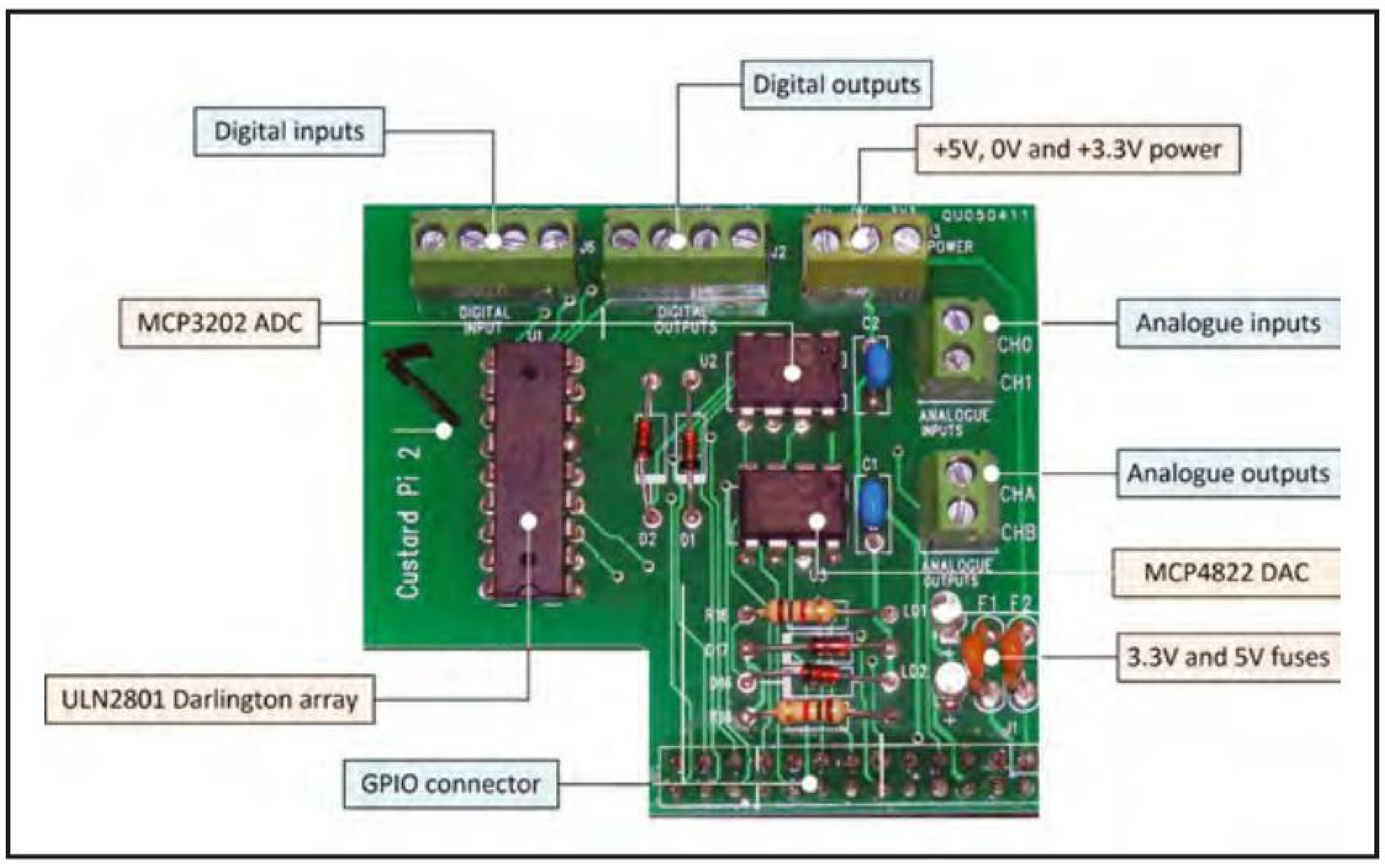

Digital inputs
Digital outputs
+5V, 0V and +3.3V power
MCP3202 ADC
Analogue inputs
Analogue outputs
MCP4822 DAC
3.3V and 5V fuses
ULN2801 Darlington array
GPIO connector
Custard Pi 2

Fig.9.17. Custard Pi 2 board layout

Note that when a Raspberry Pi GPIO pin is taken high, the corresponding output on the Custard Pi 2 will be taken low (in other words, the Custard Pi 2 inverts its digital outputs). Note also that we have tidied up at the end of the code and reset the GPIO to its un-initialised state.

Custard Pi 2 analogue I/O

The following code (from SF Innovations) uses Channel 0 of the ADC to read an analogue input in the range 0V to +3.3V (note that the voltage at the input of the MCP3202 must never exceed the voltage supplied to the chip).

```
# Custard Pi 2 analogue input
# Python 2.x
# First we need to import the required
library modules
import RPi.GPIO as GPIO
import time

# Set the GPIO pin numbering convention
GPIO.setmode(GPIO.BOARD)

# Set up the required GPIO pins as outputs
and inputs
GPIO.setup(24, GPIO.OUT)
GPIO.setup(23, GPIO.OUT)
GPIO.setup(19, GPIO.OUT)
GPIO.setup(21, GPIO.IN)

# Initialise the ADC chip
GPIO.output(24, True)
GPIO.output(23, False)
GPIO.output(19, True)

word1= [1, 1, 1, 1, 1]

GPIO.output(24, False)
vin = 0

for x in range (0,5):
    GPIO.output(19, word1[x])
    time.sleep(0.01)
    GPIO.output(23, True)
    time.sleep(0.01)
    GPIO.output(23, False)
```

```
for x in range (0,12):
    GPIO.output(23, True)
    time.sleep(0.01)
    bit=GPIO.input(21)
    time.sleep(0.01)
    GPIO.output(23, False)
    value = bit * 2 ** (12-x-1)
    vin = vin + value
    print x, bit, value, vin

GPIO.output(24, True)

volt = vin * 3.3/4096
print volt

GPIO.cleanup()
import sys
sys.exit()
```

The foregoing code provides an excellent example of how to make good use of the Raspberry Pi’s serial peripheral interface (SPI) but it might need a little explanation if you’ve not met this before.

The code begins by loading the required library modules and then initialises the GPIO port with signal assignments shown in Table 9.4. The GPIO SPI pins 24, 23 and 19 (CE0, SCLK and MOSI) are assigned as outputs, while pin 21 (MISO) is assigned as an input. At first sight the remaining code might look a little complex, but it can be broken down into two chunks (each based on a loop) and explained fairly easily.

First, the chip select (CS) line is taken low by GPIO24 in order to enable the MCP3202. Next, a five-bit control word (`word1`) is sent to the MCP3022. This consists of a sequence of five bits that are clocked out bit by bit and read into an internal register. This is achieved by means of a simple loop in which the clock (CLK) is taken from high to low on each pass through the loop. Data is valid when the clock (CK) signal sent from GPIO23 goes from low to high. Note that the first bit in the sequence is the start bit.

Next, the data can be read from the MCP3022 using a second loop, which is used to clock all twelve of the data bits into the Raspberry Pi. The data word is clocked out to the chip bit by bit using GPIO19. Once again, data is valid when the clock (CK) signal sent goes from low to high. In order to read data from the MCP3202, twelve data bits are clocked in via GPIO21. The input value can then, based on the bit position and its value, be first calculated and then printed.

Table 9.4 Signal assignments for the Custard Pi 2’s ADC

GPIO pin number (P1)	SPI signal	MCP3202 signal	MCP3202 pin number	Function
GPIO19	MOSI	DO	6	Data output from the MCP3202
GPIO21	MISO	DI	5	Data input to the MCP3202
GPIO23	SCLK	CLK	7	Clock signal (data valid when this signal goes from low to high)
GPIO24	CE0	CS	1	Chip select (taken low to read data from the MCP3202)

Home Baking Quiz

If you’ve managed to follow the series through all of its nine parts (and particularly if you’ve done some of your own *Home Baking*) you should be rapidly turning into a Raspberry Pi expert, so now’s the time to check your knowledge and find out just how much you’ve learned from the series. The following 20 questions will provide you with a means of checking what you’ve learned and, if you’ve managed to score 15 or more we reckon that you’ve become an experienced Home Baker! The answers will appear in next month’s *Teach-In 2014*.

1) How many USB connectors are fitted to a Model A Raspberry Pi?
a) None **b)** 1 **c)** 2

2) At what frequency does the Raspberry Pi’s ARM processor operate?
a) 500MHz **b)** 700MHz **c)** 1GHz

3) For reliable operation the Raspberry Pi’s 5V power supply should have a rating of at least:
a) 300mA **b)** 500mA **c)** 700mA

4) The Raspberry Pi’s composite video output provides:
a) High-resolution video with sound via an HDMI connector
b) Low-resolution video with sound via an RCA (phono) connector
c) Low-resolution video without sound via an RCA (phono) connector

5) The configuration settings for the Raspberry Pi’s operating system can be found in a file named:
a) config.txt **b)** config.sys **c)** boot.sys

6) Raspberry Pi’s GPIO connector (P1) has:
a) 16 pins **b)** 26 pins **c)** 34 pins

7) The supply voltages available from the Raspberry Pi’s GPIO connector (P1) are:
a) +3.3V only **b)** +3.3V and +5V
c) +3.3V, +5V and +12V

8) How much RAM is available in a Model A Raspberry Pi?
a) 256MB **b)** 512MB **c)** 1GB

9) Which one of the following is the Raspberry Pi’s default password?
a) password **b)** pi **c)** raspberry

10) Which one of the following is the Python shell prompt?
a) ? **b)** – **c)** >>>

11) Which one of the following commands will enable you to start the Raspberry Pi’s graphical user interface?
a) gui **b)** python **c)** startx

12) What type of computer language is Python?
a) Assembled **b)** Compiled
c) Interpreted

13) When Python is used in ‘calculator mode’ the result of entering 3 + 5 / 2 will be:
a) 2.5 **b)** 4 **c)** 5.5

14) Short sections of Python code can be called and re-used many times in a program when they are written as:
a) Initialisation routines
b) User-defined functions
c) Exception handlers

15) On the Raspberry Pi’s SPI bus, the signal referred to as MOSI is an:
a) Output from the master and an input to the slave
b) Input to the master and an output from the slave
c) Input to both the master and the slave

16) How many chip select lines are provided on the Raspberry Pi’s SPI bus?
a) None **b)** 1 **c)** 2

17) Which one of the following gives the maximum number of devices supported by the Raspberry Pi’s I^{2}C bus?
a) 32 **b)** 64 **c)** 127

18) The standard Raspberry Pi camera is fitted using the:
a) CSI connector
b) GPIO connector
c) HDMI connector

19) When the router on a home network assigns an IP address to a Raspberry Pi fitted with a wireless USB ‘dongle’ it normally uses:
a) DHCP b) HTTP c) SSH

20) To show your IP address the required command string is:
a) `ip addr show`
b) `get ip addr`
c) `show ip addr`

In next month’s Teach-In with Raspberry Pi

Next month, in the final part of *Teach-In 2014*, our *Pi Project* features the construction of a real-time clock interface for the Raspberry Pi. *Python Quickstart* will show you how tkinter can help you to improve the user interface by adding labels and buttons, and we will also have the answers to our *Home Baking Quiz*. Finally, we will also provide you with a comprehensive index to all ten parts of the series.

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HP	6032A	PSU 0-60V 0-50A – 1000W	£750
HP	6622A	PSU 0-20V 4A twice or 0-50v2a twice	£350
HP	6624A	PSU 4 Outputs	£350
HP	6632B	PSU 0-20V 0-5A	£195
HP	6644A	PSU 0-60V 3.5A	£400
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HP	8350B with 83592a	Generator – 10MHZ-20GHZ	£600
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HP	8560E	Spectrum Analyser synthesised – 30HZ--2.9GHZ	£2,500
HP	8563A	Spectrum Analyser synthesised – 9KHZ-22GHZ	£2,995
HP	8566A	Spectrum Analyser – 100HZ-22GHZ	£1,600
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HP	8672A	Signal Generator – 2-18GHZ	£500
HP	8673B	Synthesised Signal Generator – 2-26GHZ	£1,000
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HP	33120A	Function Generator – 100 microHZ-15MHZ	£395
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MARCONI	2024	Synthesised Signal Generator – 9KHZ-2.4GHZ	from £800
MARCONI	2030	Synthesised Signal Generator – 10KHZ-1.35GHZ	£950
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MARCONI	2440	Counter20GHZ	£395
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MARCONI	2955	Radio Comms Test Set	£595
MARCONI	2955A	Radio Comms Test Set	£725
MARCONI	2955B	Radio Comms Test Set	£850
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MARCONI	6200A	Microwave Test Set – 10MHZ-20GHZ	£3,000
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TEKTRONIX	2465B	Oscilloscope – 4ch 400MHZ	£600
TEKTRONIX	TFP2A	Optical TDR	£350
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R&S	SME	Signal Generator – 5KHZ-1.5GHZ	£500
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R&S	SMR40	Signal Generator – 10MHZ-40GHZ with options	£13,000
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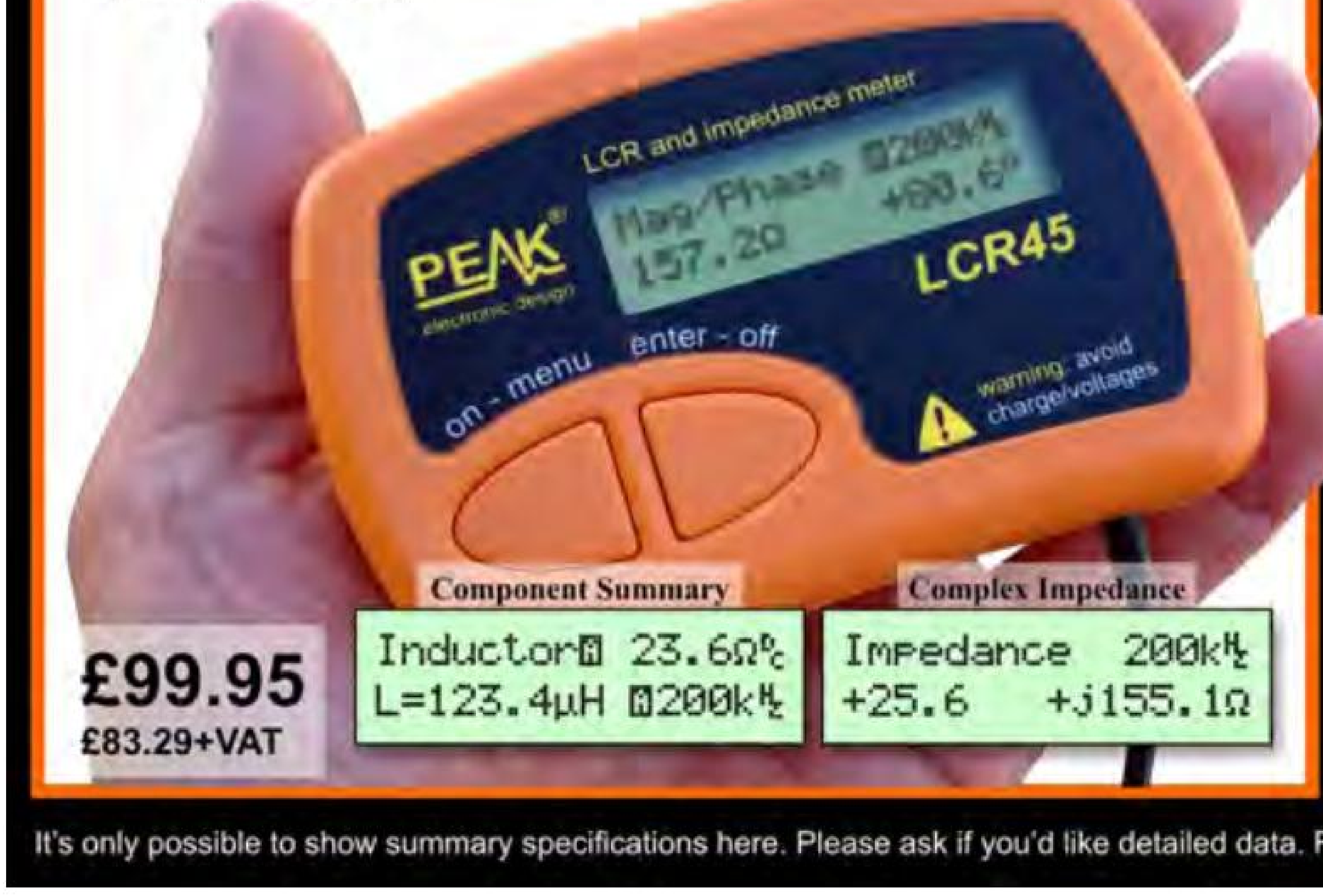

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READOUT

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say?

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All letters quoted here have previously been replied to directly

Email: editorial@wimborne.co.uk

☆ LETTER OF THE MONTH ☆

Solder talk

Dear editor
I wanted to say 'thank you' (to Alan Winstanley) for taking the time to write his *Basic Soldering Guide*. It has really helped me in gaining a better understanding of what it will take to do a proper soldering job.

While reading the *Guide* (**www.technick.net/public/code/cp_dpage.php?aiocp_dp=how_to_solder**) I came across the section discussing electronic solder and the lead-to-tin ratio. Most sources mention the ratio as being 60/40 tin/lead (Sn/Pb). While you state that: 'Normal electronics grade solder is usually 60% lead – 40% tin, and it contains cores of 'flux', which help the molten solder to flow more easily over the joint'.

This seems to be the opposite ratio. Could Alan expand on why he has it listed as 60% lead and 40% tin?

For reference, see: **http://en.wikipedia.org/wiki/Solder** – 'Alloys commonly used for electrical soldering are 60/40 tin/lead (Sn/Pb) which melts at 370°F or 188°C and 63/37 Sn/Pb used principally in electrical/electronic work.'

Jeremy Guarini, via email

Alan Winstanley replies:

Thanks for writing about my Basic Soldering Guide. *The text that you saw mirrored on an official website was written some 15 years ago or more, and things have changed since then. For environmental reasons 'lead-free' solder is now widely used (and is compulsory in the electronics industry), but solder containing lead is still fine for hobbyist use.*

To answer your question, tin-lead (60/40) is higher quality and has a superior performance to 40/60. Discerning constructors tend to use tin-lead 60/40 solder rather than lead-free or 40/60. It is worth noting that tin is much more expensive than lead, so a lower-cost solder can be manufactured by reducing the tin content. As per current London Metal Exchange raw material prices (see: ***www.lme.com/home.asp****) I see that lead is $2,035 per tonne, but tin is over ten times more expensive at $22,900 per tonne. Copper, incidentally, costs $6,550 per tonne.*

A current version of my Basic Soldering Guide *with 80 colour photos is now on Amazon Kindle. Details and links to your local Amazon site are at:* ***www.epemag.com/resources.html****. You don't need a Kindle to read it, as free software is available for PC and Mac. Soldering irons, fluxes and soldering techniques are covered in depth. My brand new Kindle book describing* Gas Soldering Irons *with some reviews of current products has just been published.*

Old projects

Dear editor
I am enquiring about the *EPE* July 2000 project *PIC-GEN Frequency Generator/Counter* circuit and the May 2001 PIC Graphics LCD Scope circuit. Can I order the programmed PIC chip from you?

Steve HG8GL

Matt Pulzer replies:

Thank you for your question about two PIC projects. I am very sorry but we no longer support such an old project, and sadly the author has now passed away. You may have luck if you ask on our forum, for example: ***www.chatzones.co.uk/discus/messages/5557/7094.html***

Simple 'Buzz box'

Dear editor
You might be interested in this simple project for your magazine. I came across your quite complex 'Motorists Buzz Box' for cars, but have found a simple Buzz Box suitable for two-stroke magneto engine timing. It would be suitable for motorcycles, lawn mowers or chain saws – see: **http://silvertecelectronics.webs.com/automotive**.

Bruce Pierson

Matt Pulzer replies

A handy little circuit indeed! Thank you Bruce.

Regulating heated gloves

Dear editor
I am preparing a modern Triumph Bonneville for a charity ride in May. I would like to reduce the voltage to the heated grips on my motorcycle – Oxford Hot Hands – they run far too hot. Could you advise a suitable variable potentiometer, with minimum of 20mm spindle, so that I can mount it inside my tank bag. The bike runs on a 12V DC supply and the heaters draw 36W with, I understand, 3A – call it 5A to be safe (over-heating?). I would like to be able to vary the voltage between 8 and 12V.

John Lewis, by email

Matt Pulzer replies:

There are several basic approaches to this, but two spring to mind as the most straightforward.

1) *You could use a pot, but since it is carrying the same current as your heating elements it will need to be able to dissipate similar amounts of heat as the elements in your gloves. This would be a clumsy and wasteful approach! You will also find that this method gives you a non-linear response to shaft position.*
2) *Use some electronics! What you want is some kind of chopper circuit or variable power supply.*

As luck would have it, we ran a very nice little switching regulator in the Jan 14 issue. It is only rated up to 1.5A, but since you say 3A gives too much heat then perhaps this circuit will be just right for you. It is super simple, cheap and easy to build.

There is an excellent description of the circuit in the construction article, so that even if this one is not powerful enough for you, you should be able *to find another that does the job. Or perhaps build one for each glove and use a single pot to control both regulators.*

www.jaycarelectronics.co.uk/productView.asp?ID=KC5508&w

Acronym explanation

Dear editor
I'm back to electronics after many years; unfortunately, I find aspects of articles unhelpful – for example, *Teach-In*.

Occasionally new acronyms come up, and some are explained, but often they are not. Possibly the same occurs with mnemonics and abbreviations. Memory not being what it was, can you point me to a source of the various 'what the hell does it mean', so that I may enjoy the many articles and projects in the *EPE* publications?

John Harkins, by email

Matt Pulzer replies:

You have two options:

1) Email me and I will try to help you, but you must specify which acronym you wish to have explained.
2) Google is your friend!

We try to be as clear as possible, and I like to think that we usually spell out an acronym if it is new or uncommon, but obviously what is 'new or uncommon' is a moveable feast.

PCB patterns

Dear editor
I am trying to download PCB layouts for the *Practical Radio Circuits* by Raymond Haigh, which started in June 2003. I have tried as per the website instructions to use **https://www.epemag.com/lib/pcb/pcb0603.zip** as the link for the PCB artwork download, but the problem is I do not get any ZIP file. Could you let me know please how I could get the artwork for this series of articles?

Turlough, by email

Alan Winstanley replies:

Thank you for the enquiry. Back in 2003, PDFs of PCBs weren't published for constructional projects and they didn't become available for free download until mid-2006. Readers would either scan 1:1 artwork directly from the page or purchase a board from our PCB service. Hobbyists would then either use 'press-n-peel' etch-resist paper or make their own acetates on a computer printer (with variable results).

For legacy projects, it would be necessary to scan the hard copy of the magazine and create 1:1 artwork directly the traditional way. Today, although readers may print from a PDF file, they would still need to use something like press 'n' peel, or make their own acetates with an inkjet printer.

*I have now revised the website with a useful link to press-n-peel (available from eBay, Maplin etc): **www.epemag.com/library.html**.*

*It is necessary to photocopy or use a PC to scan a copy of the original artwork onto a PC, then output it onto press-n-peel or a clear acetate, from which a UV-sensitive PCB can be developed. Further help may be available from constructors in our forum at **www.chatzones.co.uk** and I wouldn't rule out a fellow hobbyist offering to handle this for you for a small cost.*

*By the way, **https:// .... (a secure server address)** isn't used in the website URL.*

Teach-In connector search

Dear editor
I worked full-time in digital electronics in a national position for a well known energy supplier but I am now retired. I wonder if you can identify the supplier of a component shown in *Teach-In 2014*, Part 2, Fig 2.16 (*EPE* November 2013, p.46). The component is the individual connectors shown in your pictures, it has a green, yellow, red and black wire, each with a connector that pushes onto the 26 pins of GPIO connectors. I have tried, in vain to find a supplier of these components.

I realise that you can't get into a position that would bias you towards a particular company, but in this case, not knowing who supplies this component leaves your customers in a poor situation.

Peter Robinson

Mike Tooley replies:

Here are a few of the many suppliers. I think that the ones that I used for that particular issue came from SK Pang (it's also worth noting that a male-female lead can be made from combining a male-male with a female-female jumper – this might be a more cost-effective solution if a large quantity of leads are needed).

Male-male (assorted) jump leads:
https://www.modmypi.com/gpio-accessories/breadboarding-wire-bundle

http://www.rapidonline.com/Tools-Equipment/Breadboard-Jumper-Wires-Bundle-Of-75-34-0669

http://www.ebay.co.uk/itm/65-x-Solderless-Breadboard-Jumper-Leads-Wires-Cables-Arduino-PIC-Raspberry-Pi-/201000956114

http://skpang.co.uk/catalog/jumper-wires-kit-mm-65pcs-p-386.html

Female-female (assorted) jump leads:
https://www.sparkfun.com/products/8430

http://www.tandyonline.co.uk/100mm-female-to-female-jumper-wires-10pk.html

http://skpang.co.uk/catalog/jumper-wires-premium-150mm-ff-pack-of-10-p-1117.html

Male-female (assorted) jump leads:
http://skpang.co.uk/catalog/jumper-wires-premium-150mm-mf-pack-of-10-p-909.html

Very old project help needed

Dear editor
I have unearthed a 1983 *Logic Tutor Breadboard* with all components, but no mains adapter. Can you supply me with information on the various components and how to assemble and use it.

Dale Smith, via email

Matt Pulzer replies:

*Hi Dale, and congratulations on taking the record for asking about the oldest project! Unfortunately my collection of EPE only goes back 20 years, 31 is just too far back for me. I strongly recommend you ask on our forum: **http://chatzones.co.uk***

There is always someone who can answer an EPE-related query, even going back to its earliest days. Good luck in your quest to get the Logic Tutor *up and running*

Sparks and points

Dear editor
Just a quick note related to the February 2014 *High-Energy Electronic Ignition System* (p.10). The 'condenser' in a conventional points-and-coil ignition does more than protect the points from pitting. Tracing the layout (Fig.2) when the points are open, from +12V through the coil and capacitor to ground yields a series (acceptor) resonant circuit.

When the field in the coil collapses, it starts the resonant circuit ringing, prolonging the spark. I'm developing a spark generator for a non-motor experiment that incorporates standard vehicle ignition components in this way – you can see the improvement the condenser makes. Gone are the days when ignition was the weakest system in a petrol engine. You could carry spare points and plugs, and if the car broke down, change them by the roadside and be away again in minutes. Static points settings needed just a slotted screwdriver (to turn the entire distributor on its mount) and a lamp with a length of wire.

One day, a motorist had finished some do-it-yourself work of this nature, but now the car wouldn't start. Having run out of ideas and not being covered for breakdowns at home, he pushed the car just over the required quarter of a mile (luckily downhill!) so as to be eligible for help. The technician arrived and verified that the hapless motorist had 'driven from home' and then broken down at this very spot. 'In that case, sir, could you explain to me how you got this far with the rotor arm missing?'

Godfrey Manning G4GLM, Edgware

Matt Pulzer replies:

Thank you Godfrey, interesting and entertaining!

Max's Cool Beans

By Max The Magnificent

Welcome to the Pleasure Dome!

Well, things are certainly racing along here in the 'Pleasure Dome' (my office). What? You want to see what my office looks like? Well, here's a link to a blog containing some photos and a video of my lair (**http://ubm.io/1lwt2DS**).

Prognostication Engine update

In previous columns, I introduced my current hobby project – my *Pedagogical and Phantasmagorical Inamorata Prognostication Engine*. This is not as easy to say as you might think; in fact, it's a bit of a tongue twister. This is unfortunate, because in a few days' time I'm going to be giving a presentation on this little beauty at the *EE Live! 2014 Embedded Systems Conference and Exhibition* in San Jose, California. This explains why I'm currently to be seen walking around muttering 'Pedagogical and Phantasmagorical Inamorata Prognostication Engine' under my breath, which has earned me some funny looks from passersby.

This really is starting to look very cool indeed. I've got about 120 tri-color LEDs on the brass front panels, each mounted under a faux mother-of-pearl 'dot.' These shimmering white dots look amazing when embedded in the front panels. I've also got a bunch of antique toggle switches and push-buttons, five modern potentiometers decked out with antique knobs, and a collection of antique analogue meters (the meters have black bakelite cases and rims that look amazing when presented on the brass panels). As you may recall, the potentiometers are motorised. The idea is that if anyone turns one to modify its setting, the others will automatically change their settings to compensate. Sometime later, when no one is looking, all of the potentiometers will stealthily return to their original positions and settings.

Arduino Mega control

I'm using an Arduino Mega to control everything. This is based on an 8-bit Atmel microcontroller running at 16MHz. Of course, one always wants as much power as one can get. Thus, given a choice, I would be tempted to use a chipKIT Max32, which is the same form factor as the Arduino Mega, but based on a 32-bit MIPS processor core running at 80MHz with 512K of Flash program memory and 128K of SRAM data memory. The reason I'm sticking with the Arduino Mega is that I'm using motor controller shields and tri-color NeoPixel LEDs from **adafruit.com**, and these only work with Arduino Unos and Megas (the libraries make low-level calls to the Atmel MCU).

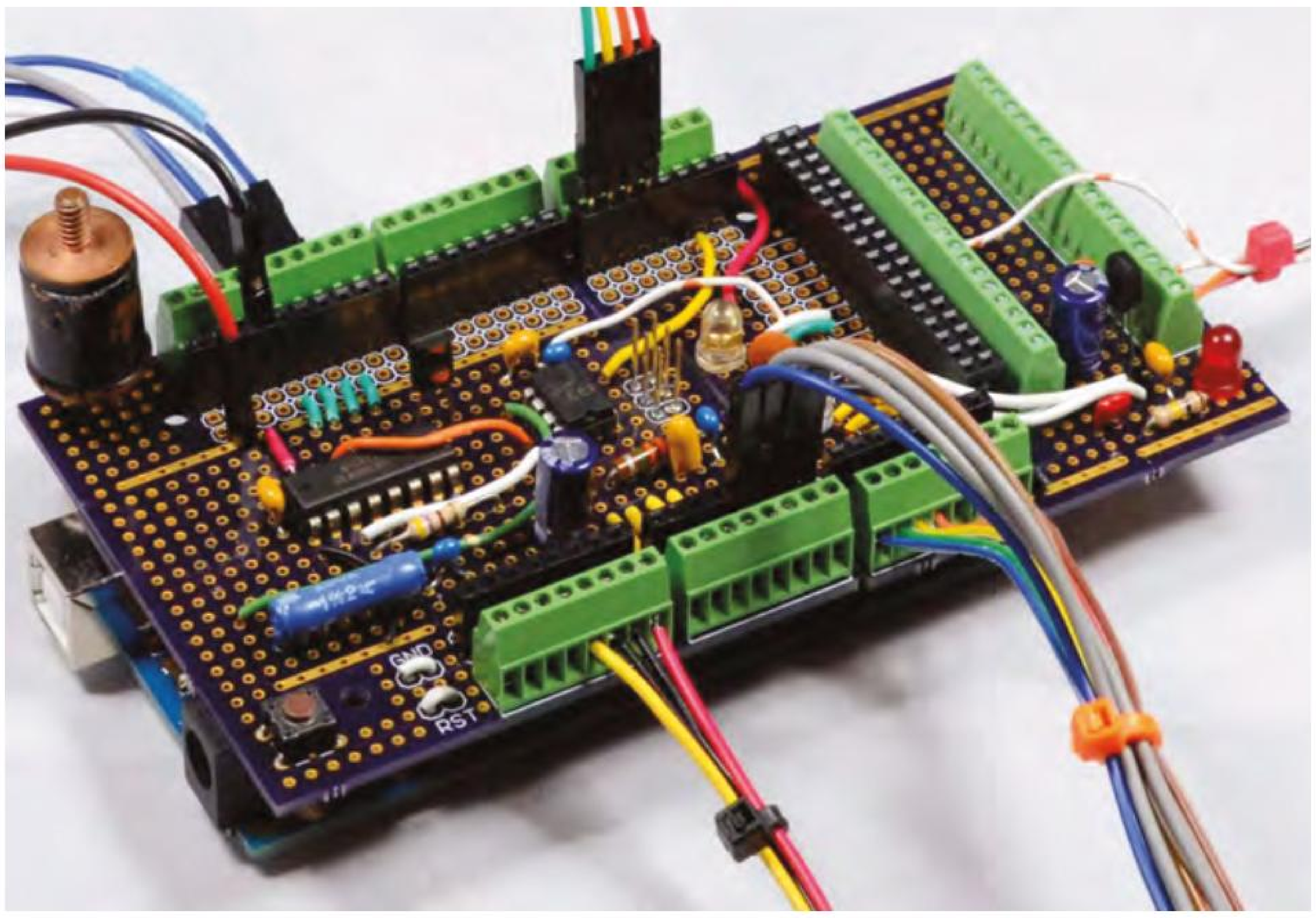
Searching for the right prototyping system

A recurring theme with this project is that it involves a lot of experimenting and prototyping. There are prototyping shields available for Arduinos, but most of them require you to use solder joints to connect wires from the outside world. This is a real pain if you are constantly connecting, disconnecting, and reconnecting things. I looked around and found a proto-shield that boasted screw-block terminals, but this was only available for the Arduino Uno.

Screw-block assembly

I chatted about this with my friend Duane Benson, who is the marketing manager for a company called Screaming Circuits. Duane is building a robot avatar that involves a number of different microcontrollers, including Arduinos. Between us, we came up with a rather cunning design for what we now call our 'Bodacious Universal Screw-Block Proto-Shield for Arduino'.

One thing we noticed about existing screw-block proto-shields is that each screw-block terminal is hard-wired to its associated header pin and also to a single through-hole pad in the prototyping area. Now, this is great if you want the screw-block terminal to be connected directly to its header pin, but what do you do if you want to add components between the screw-block terminal and the header pin? Our solution was to wire each screw-block terminal and its associated header pin to two separate through-hole pads in the prototyping area. If you want the screw-block terminal and its header pin to be connected, you can simply add a jumper; otherwise, you can wire them to components in the prototyping area. This is such a simple idea, but it's amazingly effective – I cannot understand why no one else has done it before.



My Kickstarter project – 'Max and Duane's Bodacious Universal Screw-Block Proto-Shield', mounted on an Arduino Mega

Kickstarter fun

Duane and I received so much interest in these little beauties that we decided to launch a Kickstarter project (**http://kck.st/1faeHZY**). I tell you, I had no idea how complicated the manufacturing and production side of things can be. For example, the circuit boards have different price breaks at say 100, 500, and 1,000 boards; similarly for the connectors. If we assume that we are only going to get a few supporters, then we need to go for the smaller production numbers, but this will make the boards more expensive. Alternatively, if we assume that we are going to get a lot of supporters, then we can base everything on larger production numbers, which will reduce the pricing, but increases the chances of the project failing if we don't generate sufficient interest. All of this makes my brain ache.

Another thing we had to do was create a special website for our project. Our friend Denis Crowder created the **MDGalactic.com** site for us (we decided to call ourselves 'Max & Duane Galactic Enterprises', because we don't want to limit ourselves in the future). This is actually quite a tasty little website, not the least that it's mobile-friendly – the content automatically scales itself and rearranges itself depending on whether you are viewing it on a large screen or a tablet or a handheld device.

One thing I'm really rather proud of is the documentation we've created for assembling and using our proto-shields (you can bounce over to **MDGalactic.com** and download this to take a look at it if you wish). This took a lot of work, but I remember what things were like when I was starting out and I was 'dazed and confused' and didn't know things like the fact that it doesn't matter which way round you mount a momentary push-button switch, for example.

So, that's where we are at the moment. Our Kickstarter project launched just a few days ago as I pen these words. By the time you read this we will know whether it succeeded or failed. Fortunately, I already have my own prototype screw-block proto-shield, which I'm happily using in my *Inamorata Prognostication Engine*. Even so, I would really like the Kickstarter project to succeed, so I'm keeping my fingers crossed for luck. Until next time, have a good one!

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PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

Assembly language to C

THIS month, we complete the 'port' of the development board template code from assembly language to 'C', the shell of which we started in last month's issue. Only the interesting snippets of the code are shown in this article; the full project files can be downloaded from the magazine website against this month's issue.

Why the 'C' language?

The question has come up several times in the last few months, 'Why change from assembly language to C?' and 'Why to C rather than some other language?'

Software written in assembly language is not easily 'ported' between different processors, nor is it easy to re-use. Why? It's because assembly language is a direct, one to one mapping to the processors internal machine language. The assembly language instruction

```
MOVLW   0x56
```

is the direct replacement for the machine instruction

```
0E56
```

Assembly language is just a human-readable version of machine language.

Naturally, each type of microcontroller, especially from different manufacturers, will have a different machine language, and therefore a different assembly language.

Higher level languages such as 'C' provide a new language 'layer' on top of assembly language, a form of abstraction. The 'C' compiler will then read this language and convert it into the machine language of the processor you choose. The Microsoft Visual Studio compiler translates the code into Intel processor machine code; the Microchip xc8 compiler converts the code into PIC12, 16 or 18 family microcontroller machine code. The Open Source GCC compiler supports hundreds of different processors, including both Intel and Microchip ones.

The 'C' programming language, being a high level language, enables us to express our programs in a more abstract way – and therefore, write more complex programs, more easily. We will see that in action when we re-implement the kitchen timer in 'C'. Programs written in the 'C' programming language may not be as fast as assembly language, although of all the high level languages, C is the closest to assembly in terms of performance. The machine code generated by the compiler is normally bigger for the same result. Creating smaller, faster programs is not always necessary, however. If you have plenty of FLASH memory space, or the program does not need to run fast, there would be no benefit to writing the program in assembly language. Remember, we humans have a different interpretation of 'fast' compared with microcontrollers. We might consider the microcontroller updating the LCD within a quarter of a second as 'fast'. A microcontroller however could update the display twenty times in quarter of a second. So how fast something runs is very relative!

Completing the template

Let's get back to completing the port of the code. We will start with the timer module, as it is one of the simplest.

If you recall with the 'C' language there are two files created when we create a code module; the source file, whose filename ends in `.c`, which contains the actual code. Then there is the header file, ending in `.h`, which contains the declaration of the functions and symbols. The header file is included by any other source file that wants to use the functions within the source file.

Starting with the source file, we can do a simple port of the symbols from the assembler file:

```
TMR0_DISABLE         EQU    0x00
TMR0_ENABLE          EQU    0x83
TMR1_CONF            EQU    0x8E
```

becomes

```
#define TMR0_DISABLE        0x00
#define TMR0_ENABLE         0x83
#define TMR1_CONF           0x8E
```

These symbols are defined in the source file rather than the header file as no other module will need to 'know' about them – only the functions within the `timer.c` module use them.

Now let's port one of the functions. Here's the initialisation routine for `timer0`, bearing in mind the comments are excluded here to keep the text readable. In the source code, the comments have been moved across.

Original, in **timer.asm**:

```
Timer0Init
      movlw  TMR0_DISABLE
      movwf  T0CON

      return
```

new, in **timer.c**:

```
void Timer0Init( void )
{
     T0CON = TMR0_DISABLE;
}
```

So that's a function that returns nothing to the calling function (as indicated by the first 'void' statement) and takes no parameters (the second 'void' statement.) Notice how the function is simpler than the assembler version.

Before we can compile these code changes we must also add a reference to the **pic18.h** header file in **timers.c**, so we can gain access to the symbol names for the various hardware registers, whose names appear in the datasheet (T0CON for example.) How did we know to include that particular header file? Unfortunately, this is just something you discover through reading other people's code. You *can* just include the PIC18F27J13-specific header file, but using **pic18.h** makes your project more flexible – if you change the processor, the correct symbols will be automatically loaded. How does this work? It's quite simple; when you selected the processor during the project creation, MPLAB-X automatically creates a symbol named **_18F27J13**. The header file **pic18.h** includes another header file called **pic18_chip_select.h**, and that file contains a long list of further include files, one for each PIC18 processor that exists. Here is a snippet from that file:

```
#ifdef _18F26K80
#include <pic18f26k80.h>
#undef _HEADER_NOT_FOUND
#endif

#ifdef _18F27J13
#include <pic18f27j13.h>
#undef _HEADER_NOT_FOUND
#endif
```

The `#ifdef _18F27J13` statement is like an ‘if’ statement in ‘C’ – if that symbol name has been defined, then the text between the coresponding **`#ifdef`** and **`#endif`** sequences should be included. Otherwise, ignore them. The file **pic18_chip_select.h** is 1500 lines long, but we only end up using about 20 of them! All of this is happening ‘under the hood’ of the compiler, and it isn’t something we really need to know – but its interesting to see the technique used; you may end up using a similar trick yourself, although perhaps not as complicated.

When this code is added and the project recompiled, something strange happens to our program file – nothing! There is no change in the amount of memory used, either FLASH or RAM. This is because nothing *calls* the `Timer0Init` function, therefore, during the link stage of the compilation process, the linker will not place the function into our program. The compiler is smart – if it notices that some compiled code is not used, it will discard it. (The compiler can get this wrong sometimes, as we may see later on in the series.) Let’s go and make it be included, to see how much the memory usage increases by.

We add a reference to the header file, and a call to the initialisation routine within the `main()` `function` in **main.c**:

```
#include “timer.h”

int main(int argc, char** argv)
{
    Timer0Init();
    return (EXIT_SUCCESS);
}
```

and then we add the function declaration to the header file **timer.h**:

```
void Timer0Init( void );
```

Now when the project is built, we see that the data usage is unchanged, but that the code space has increased by 10 bytes – *exactly* what the assembly language version takes. So in this case, the ‘C’ code is as efficient as assembly.

The next section of code to port is the **Timer1** initialisation. The work here is simpler as we have already included the **pic18.h** header file.

The original code

```
Timer1Init
    bcf     PIR1, TMR1IF
    clrf    TMR1H
    clrf    TMR1L

    ; Enable the 32KHz oscillator on Timer1
    ; for use as an accurate timebase.
    movlw   TMR1_CONF
    movwf   T1CON
    bsf     PIE1, TMR1IE
    bsf     INTCON, PEIE
    bsf     INTCON, GIE
    bsf     T1CON, TMR1ON
    return
```

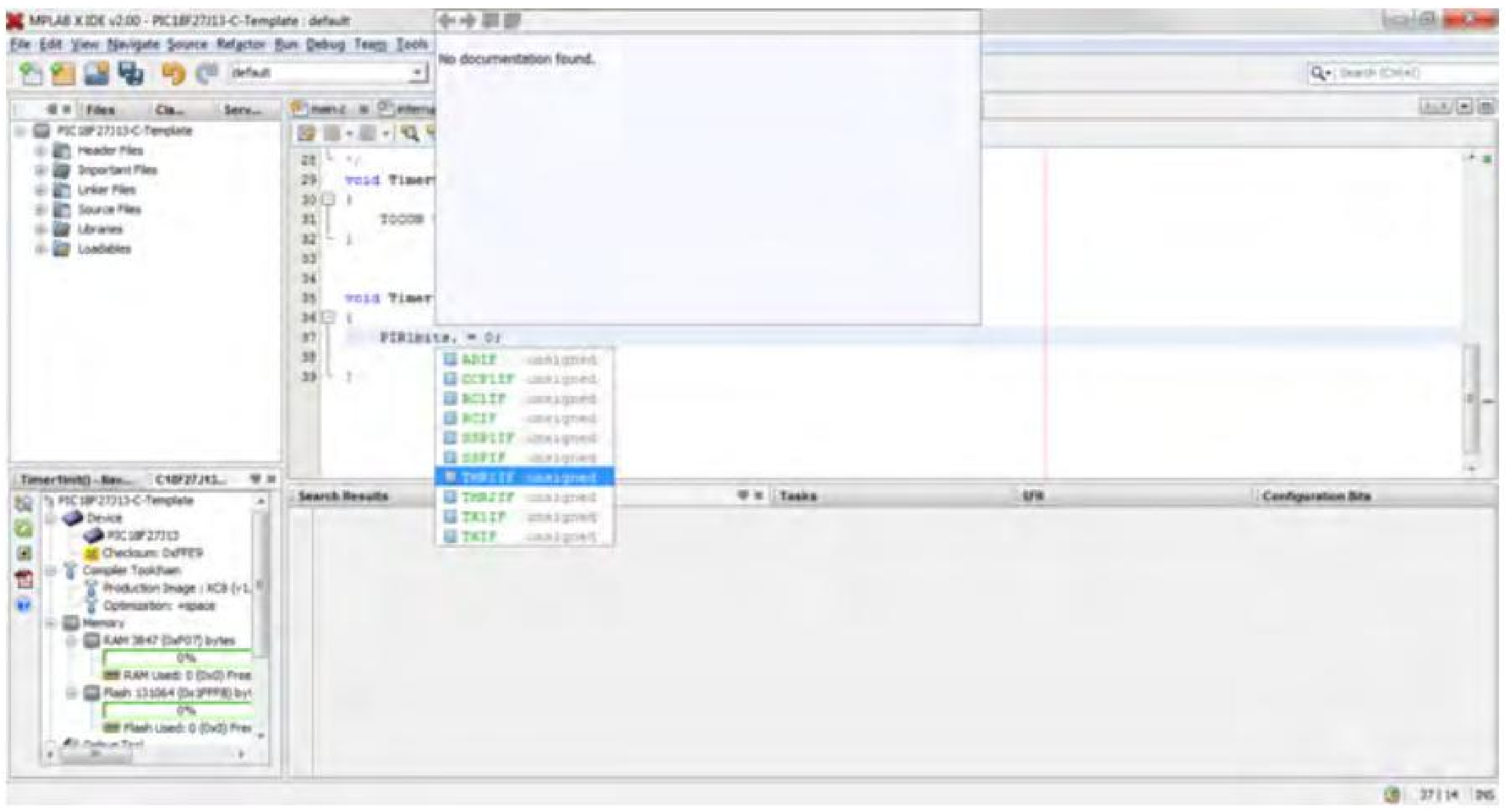
translates to the following, in **timer.c**:

```
void Timer1Init( void )
{
    PIR1bits.TMR1IF = 0;
    TMR1H = 0;
    TMR1L = 0;

    // Enable the 32KHz oscillator on Timer1
    // for use as an accurate timebase.

    T1CON = TMR1_CONF;
    PIE1bits.TMR1IE = 1;
    INTCONbits.PEIE = 1;
    INTCONbits.GIE = 1;
    T1CONbits.TMR1ON = 1;
}
```

One of the nice features of the MPLAB X IDE is that for data structures that it recognises – both internal ones, and those you create yourself – as you type the symbol names in, the IDE will display a list of fields within the data structure, as you can see in Fig.1. This can save a certain amount of ‘ping-ponging’ between datasheets and code windows.


MPLAB X IDE v2.00 - PIC18F27J13-C-Template : default
File Edit View Navigate Source Refactor Run Debug Team Tools
Files
Search Results
Tasks
Configuration Bits
ADIF
CCP1IF
RC1IF
SSP1IF
TMR1IF
TMR2IF
TX1IF

No documentation found.

Fig.1. Dynamic Help in the IDE

Again, to complete this code port we add the function declaration to the header file **timer.h**:

```
void Timer0Init( void );
void Timer1Init( void );
```

and add a call to it in **main.c**:

```
#include “timer.h”

int main(int argc, char** argv)
{
    Timer0Init();
    Timer1Init();
    return (EXIT_SUCCESS);
}
```

When compiled, this added 28 bytes to the FLASH memory usage. That’s eight more than the assembly code. Proof that ‘C’ is not always as efficient as assembly language!

Things start to get more interesting now, as we look to convert the **usleep** routine. This is what it looks like in assembler:

```
usleep:
    bcf     INTCON, TMR0IF
    movlw   TMR0_ENABLE
    movwf   T0CON
usl001:
    btfss   INTCON, TMR0IF
    goto    usl001
    movlw   TMR0_DISABLE
    movwf   T0CON
    return
```

It’s straightforward with the exception of the `btfss` instruction (test a flag, skip the next instruction if it is set) and `goto`, which together form a loop. Although the ‘goto’ statement does exist in the ‘C’ language, better statements exist for performing loops. This routine is a good candidate for a `while` or `do` loop; we will go with the `while` statement. Here is the ‘C’ code:

```
    INTCONbits.TMR0IF = 0;
    T0CON = TMR0_ENABLE;

    while ( !INTCONbits.TMR0IF )
        /* do nothing */ ;

    T0CON = TMR0_ENABLE;
```

Notice that we did not complete the function 'prototype' (the first line of a function, containing the return type, function name and parameter list.) In the assembly version, **usleep** is used in conjunction with some macros that place the timer delay value into the TMR0 register before usleep is called. In 'C', we can do that more elegantly by passing the delay value into the function. Here is the complete version:

```
void usleep( unsigned short delayValue )
{
    TMR0H =  delayValue >> 8;
    TMR0L = delayValue & 0xFF;

    INTCONbits.TMR0IF = 0;
    T0CON = TMR0_ENABLE;

    while ( !INTCONbits.TMR0IF )
        /* do nothing */ ;

    T0CON = TMR0_ENABLE;
}
```

We complete this delay routine's implementation by placing its prototype in the header file, next to the other two, and add the definition of the six delay times (remember, we place in the header file function names and value definitions that we want to make available to other modules.)

```
#define USLEEP_2US       65534
#define USLEEP_100US     65461
#define USLEEP_200US     65386
#define USLEEP_3MS       63286
#define USLEEP_8MS       59536
#define USLEEP_80MS      5536

void Timer0Init( void );
void usleep( unsigned short delayValue );
void Timer1Init( void );
```

So that completes the timer module translation to 'C'. Translation of the **lcd.asm** module follows a similar approach; things get interesting again when we get to the interrupt module.

Creating interrupts in 'C' is actually more difficult than in assembler; enabling and configuring the interrupt source is very similar, but creating the interrupt routine in 'C' requires some non-standard 'C' language, and the way this is done tends to vary between 'C' compilers. You have to do two things:

Tell the compiler this is an interrupt routine;
Tell the compiler what interrupt vector to match the routine to.

In assembler we need only do this:

```
 org 8
 goto      InterruptHandler
```

which places a 'jump' from the interrupt vector location (8) to the name of our interrupt routine.

The PIC18F27J13 has the concept of two interrupt vectors, one high priority, the other low. This can be very confusing, so we use the simpler, single vector compatibility mode. The datasheet explains it nicely:

> *When the IPEN bit is cleared (default state), the interrupt priority feature is disabled and interrupts are compatible with PIC mid-range devices. In Compatibility mode, the interrupt priority bits for source have no effect. INTCON<6> is the PEIE bit, which enables/disables all peripheral interrupt sources. INTCON<7> is the GIE bit, which enables/disables all interrupt sources. All interrupts branch to address 0008h in Compatibility mode.*

Thankfully, in 'C' this is easy to handle, once you know how it works:

```
void interrupt InterruptHandler( void )
{
        ...
}
```

The keyword `interrupt` tells the compiler to make the function `InterruptHandler` an interrupt routine, preserving the processor registers on entry, and restoring them on exit. It also places a `jump` instruction to this routine at the interrupt vector location, 0008h.

The remaining porting activities are uninteresting, requiring similar changes as before. In all, it took four hours to convert the assembly language template files to 'C', and that included testing the code afterwards. The template software assumes the LCD connections are as shown in Fig.2, the connections we have been using for our 'Kitchen Timer' project.

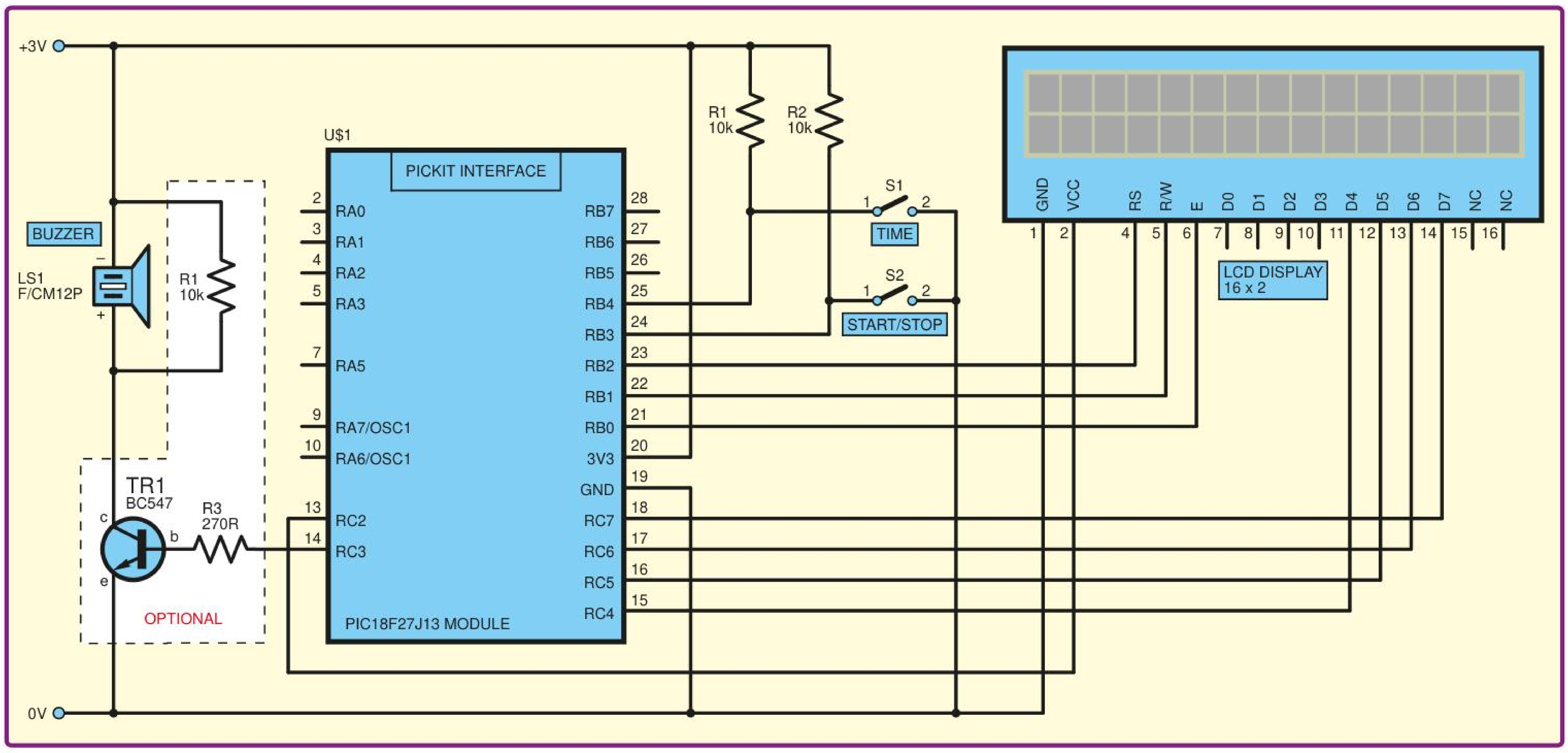


Fig.2. Circuit diagram matching the template files

Coding Style

There are two questions that seem to be asked each year by students of programming: ‘what base should I write numbers in?’ and ‘what coding style should I use?’

The first question is the easier of the two. Here is an example, picked out from our own code:

```
 TMROH = delayValue >> 8;
 TMROL = delayValue & 0xFF;
```

We are writing to the high and low bytes of the same timer, yet we use two different bases!

The reason for this is simple. When writing a number, use the base that makes sense for the *operation* being performed. In the above example, with the first line, we want to shift the `delayValue` number down by eight bytes. It seems reasonable to write that in decimal. In the second line, we are masking out the upper 8 bits, leaving only the lower 8 bits present. This is a *bit mask*, and it makes more sense to write this in binary, or hexadecimal. To answer the question, however, it doesn’t really matter which form you use; it’s more a question of style. Being consistent is more important.

Which brings us to the next point: ‘What coding style should I use?’ Believe it or not, the way that you format your code matters – it can make the difference between something being a joy to read, or very unpleasant. Here is an example. The same code, formatted differently:

```
      unsigned char val; // value to write to the buffer
      unsigned char pos; // position of the cursor on the line
      unsigned char lp; // loop counter

      for (lp = ‘A’; lp <= ‘Z’; lp++) {
       putch(‘.’);
       putch(lp);
      }
```

verses

```
// value to write to the buffer
unsigned  char  val;
// position of the cursor on the line
unsigned char pos;
unsigned char lp;  // loop counter

for ( lp=’A’;lp<=  ‘Z’;lp++)
{ putch(‘.’);putch(lp);}
```

Both work fine, but would you want to spend a whole day, day after day, reading code like the second example?

There are a number of different styles (sometimes called ‘churches’, for the religious devotion they can inspire) and we favour the ‘K&R’ style, named after the inventors of the ‘C’ programming language. Which gives some authority to the style, we think! A good explanation can be found at:

http://en.wikipedia.org/wiki/Indent_style,

and a slightly more tongue-in-cheek, though no less relevant one, can be found at:

www.coreboot.org/Coding_Style.

Enjoy.

Kickstarter update

The Kickstarter project – our campaign to make available a low-cost, pre-built version of the development board – is well on its way to success. It is standing, currently, at 146% of pledges required and so should, by the time you read this article, have finished the funding round and be about to enter the manufacturing stage. Our thanks to all you magazine readers (and others, through the Kickstarter website) who made this possible. It’s been a fascinating learning experience, and a great deal of fun. The hard work – getting over 200 boards manufactured and assembled – starts soon! All the same, I am looking forward to completing this and starting the next project.

Although the Kickstarter project itself will close down, it will still be possible to purchase boards through the author’s website, **mjhdesigns.com**.

To catch up on the final outcome of the funding round, go to **Kickstarter.com** and search for ‘LPLC development board’

Next month

Next month, *finally*, we implement the kitchen timer in C, using our newly created template project. And if there is time, introduce some SPI routines into the template project files, to enable driving a sweet, cheap, colour LCD display.

Not all Mike’s technology tinkering and discussion makes it to print. You can follow the rest on Twitter at ***@MikeHibbett****, and from his blog at* ***mjhdesigns.com***

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INTERFACE

By Robert Penfold

Multiplying ins and outs

WHEN interfacing your own add-ons to computers, you are often faced with the prospect of 'getting a quart into a pint pot', or more specifically, something like getting four output lines to control eight devices. This tends to be a frequent problem with something like a PC printer port or a basic 8-bit input or output port that does not even have any handshake lines. With its eighteen lines, each of which can be individually programmed as an input or an output, this is less likely to be a problem with the GPIO port of a Raspberry Pi.

Of course, even with the eighteen lines of the Raspberry Pi's GPIO port you could still get 'caught short', and with control applications you can find that the available lines quickly get used up as the system develops. Even if there are sufficient lines to control everything, operating on the basis of one line per controlled device might not be the neatest approach. Using sixteen output lines and an outsize connecting cable could be considered as doing things the hard way if four lines and a thin cable could be made to perform the same task.

Three to eight on

Some applications require something along the lines of eight outputs, but with only one output at a time actually set to the active state. In other words, what is effectively an eight way selector switch under computer control. This could obviously be handled using eight output lines, but it would be an inefficient way of handling things. Eight output lines can accommodate up to 256 different binary values, but only eight of the available values would ever be used. The normal solution is to use an eight-line decoder chip, such as the 74LS138. This chip has a 3-bit binary input port and eight output lines numbered from 0 to 7. Inputting a binary value on the inputs results in the corresponding output going low (logic 0). All the other outputs are high (logic 1).

With this method, up to eight outputs can be controlled from just three output lines of the computer port, but with the limitation that it is not possible to have more than one line at logic 0. Another point to bear in mind is that there is no option of having all the outputs high (logic 1) and none of the controlled devices selected, since outputting a value of zero to the inputs results in output 0 going low. However, it is possible to have an 'off' state by leaving output 0 unused, which then gives seven outputs plus an off state.

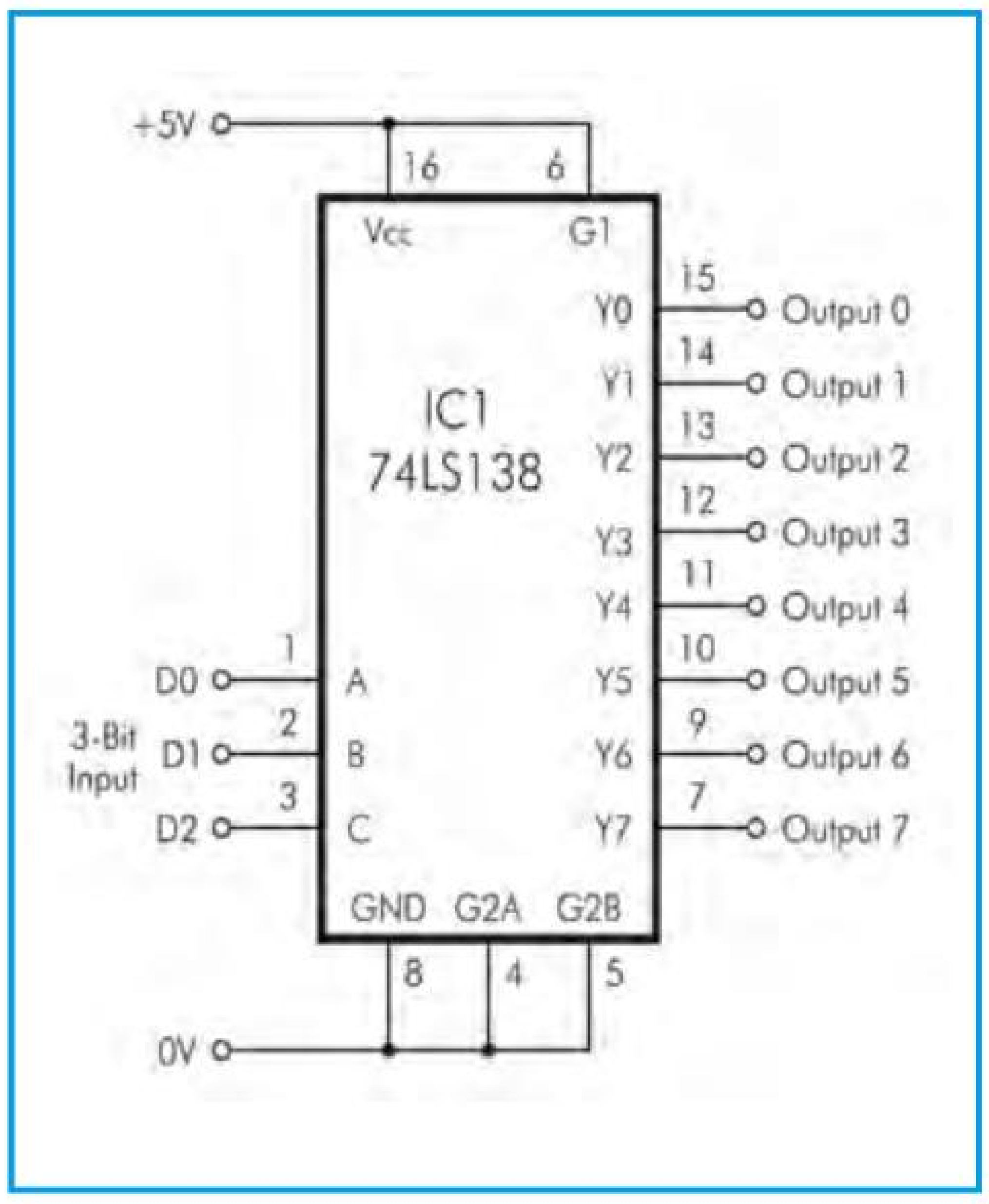

Fig.1. The 74LS138 has three data inputs and eight outputs. One output is low and the other seven are high, enabling it to operate as a sort of 8-way selector switch

The 74LS138 has some additional inputs. There are two negative-enable inputs at pins 4 and 5, and a positive enable input at pin 6. These must be connected to the relevant supply rails in order to switch on the output section of the device. Fig.1 shows the basic circuit for a 74LS138 as a 3-to-8-line decoder. I found no problems when driving a 74LS138 from the 3.3V logic outputs of a Raspberry Pi, but for optimum reliability, suitable buffering should be used. The 74LS138N has a standard 16-pin DIL encapsulation, but there are also surface-mount versions.

Flip-flops

The limitation of only one active output at a time is clearly a fairly major one. It is actually possible to overcome it by having a divide-by-two flip-flop circuit at each output. It is then possible to toggle each output. The basic scheme of things would be to have output 0 left unused, but there would be a flip-flop circuit at each of the other seven outputs. To switch on the device at output 4, a value of 4 would be written to the decoder circuit, followed by a value of zero.

This would generate a pulse on output 4 that would toggle the flip-flop and set its output high. Repeating the process would generate another pulse and toggle the output of the flip-flop back to the low state. With anything of this type, the software must keep track of the current state of each output so that it stays synchronised with the hardware, but it does genuinely provide individual control of seven outputs using just three outputs of a computer port.

Even without any additional hardware this method of control is well suited to many practical applications. At a very basic level it could be used in something like a moving light display. In a more sophisticated application it could be used as part of an auto-ranging meter of some kind. The basic scheme of things for auto-ranging is to have the software start at the most sensitive range and move on through the higher ranges until an in-range reading is obtained. That reading is then displayed. The outputs of the 74LS138 could be used to control (say) a set of CMOS analogue switches that act as the range selectors. Likewise, with a system that has numerous analogue sensors it would be possible to use a setup of this type to select one of up to eight sensors and take a reading from it.

Doubling up

Of course, by using more outputs of a port it is possible to go beyond an 8-way selector. The 74LS154 provides 4-to-16-line decoding, and is similar in operation to the 74LS138. It lacks a positive enable input, but two negative enable inputs (pins 18 and 19) are included. The basic circuit for a 4-to-16-line decoder using a 74LS154 is shown in Fig.2. The 'N' version of this chip has a 24-pin DIL encapsulation with the wider (0.6-inch) row spacing.

A practical problem with the 74LS154 is that these days it can be difficult to obtain any version of it, and the price can be relatively high if you can find one. An alternative way of obtaining a 16-way selector is to use two 74LS138 chips with the fourth output of the computer port used to control the enable input of one chip, and the negative enable input of the other. This method of operation is shown in the circuit of Fig.3. The 74LS138 does not have tristate outputs, and setting an enable input to the inactive state does not set the outputs at a high impedance state. Instead it sets all eight of its outputs high.

I assume that the point of this is that it simplifies the task of using two 74LS138 chips to produce a 4-to-16-line decoder. In fact, it is not necessary to have any

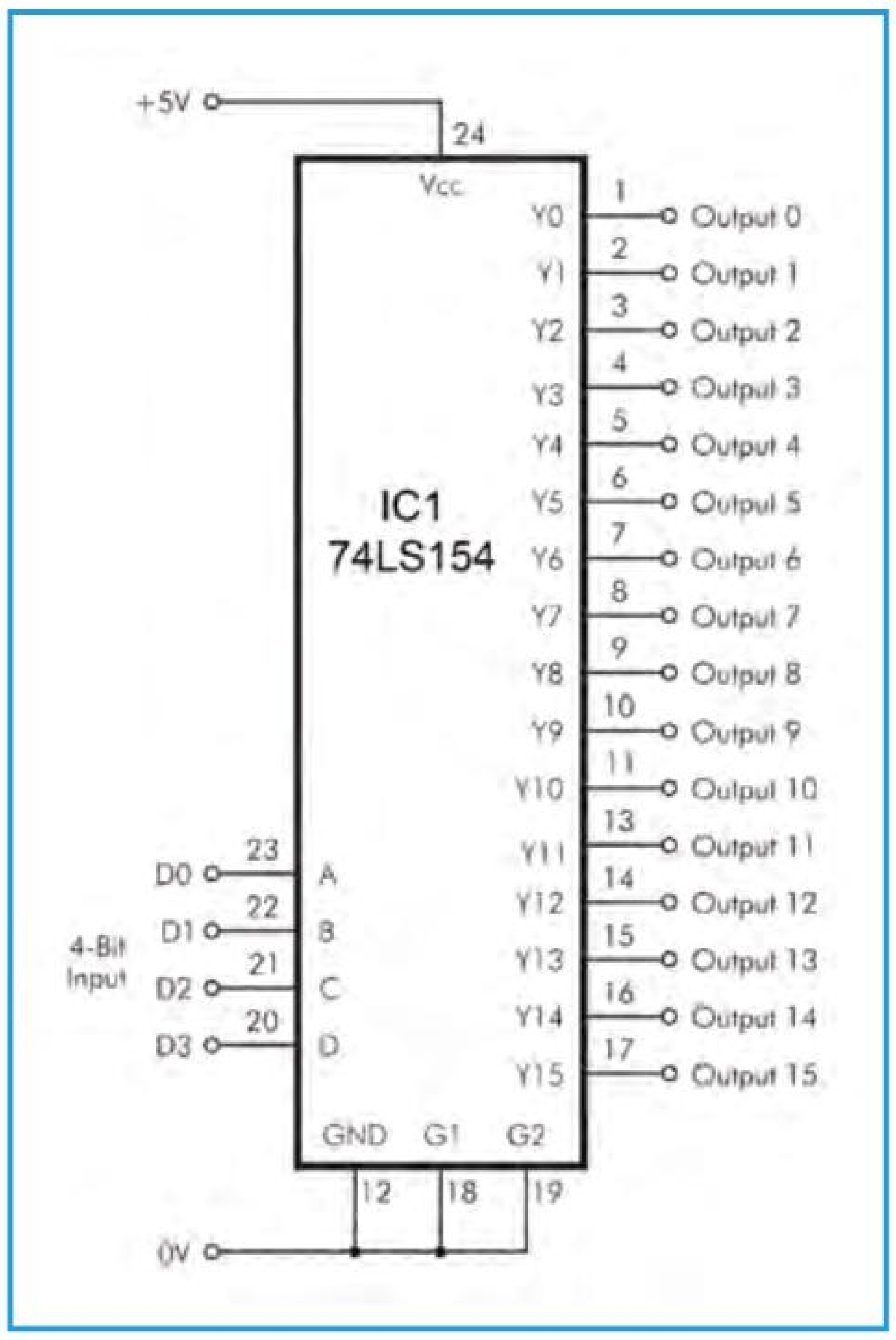
+5V
24
Vcc
IC1
74LS154
Y0
Y1
Y2
Y3
Y4
Y5
Y6
Y7
Y8
Y9
Y10
Y11
Y12
Y13
Y14
Y15
1
2
3
4
5
6
7
8
9
10
11
13
14
15
16
17
Output 0
Output 1
Output 2
Output 3
Output 4
Output 5
Output 6
Output 7
Output 8
Output 9
Output 10
Output 11
Output 12
Output 13
Output 14
Output 15
D0
D1
D2
D3
4-Bit Input
23
22
21
20
A
B
C
D
GND
G1
G2
12
18
19
0V

Fig.2. The 74LS154 takes things a stage further than the 74LS138. It has four inputs and sixteen outputs, enabling it to operate as a 16-way selector

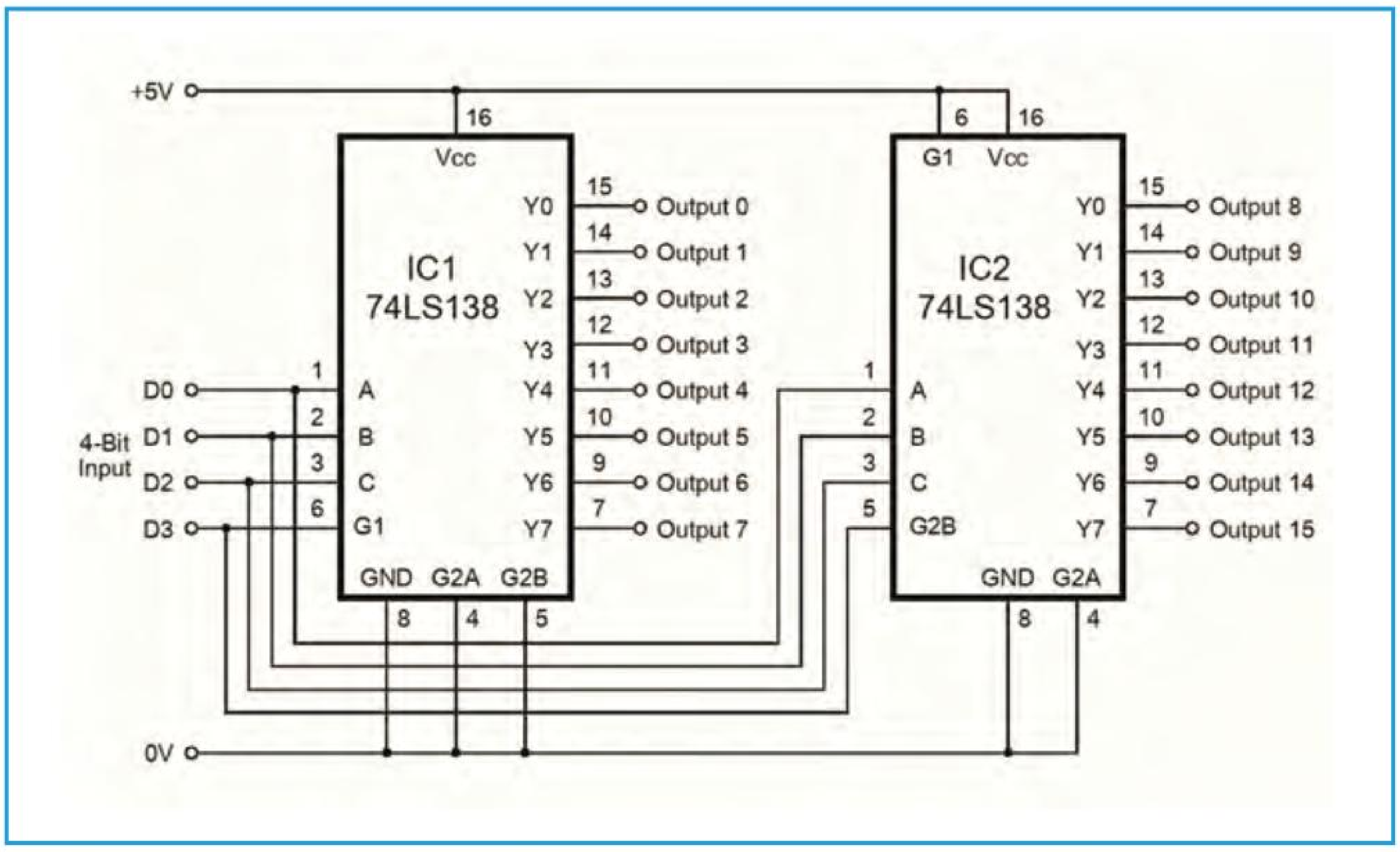
+5V
16
Vcc
IC1
74LS138
Y0
Y1
Y2
Y3
Y4
Y5
Y6
Y7
15
14
13
12
11
10
9
7
Output 0
Output 1
Output 2
Output 3
Output 4
Output 5
Output 6
Output 7
D0
D1
D2
D3
4-Bit Input
1
2
3
6
A
B
C
G1
GND
G2A
G2B
8
4
5
6
16
G1
Vcc
IC2
74LS138
Y0
Y1
Y2
Y3
Y4
Y5
Y6
Y7
Output 8
Output 9
Output 10
Output 11
Output 12
Output 13
Output 14
Output 15
1
2
3
5
A
B
C
G2B
GND
G2A
8
4
0V

Fig.3. It is possible to use two 74LS138 chips to act as a 4-to-16-line decoder circuit. This circuit utilises the Enable input of IC1 and a negative Enable input of IC2, so that only one or other of the chips is active at any one time

hardware other than the two 74LS138 chips. IC1 is enabled and works normally when the fourth output (D3) is high, but IC2 is set to the inactive state and all its outputs go high. Conversely, setting D3 low enables IC2 and it then works normally, but IC1 is set to the inactive state with all eight of its outputs high. Thus, only one of the 16 outputs will be low at any one time, and the required 4-to-16-line decoding is obtained.

Sensor selection

If it is necessary to monitor several peripheral devices, such as sensors in an alarm system for example, it is not essential to have a separate input to monitor each one. Some simple gating is all that is needed in an application where it is merely necessary to know that a sensor has been activated, and it does not matter too much which particular one has triggered the system. For example, one input could be used to monitor eight sensors via an 8-input AND gate. One or more of the inputs going high would cause the output of the gate to go high and activate the system.

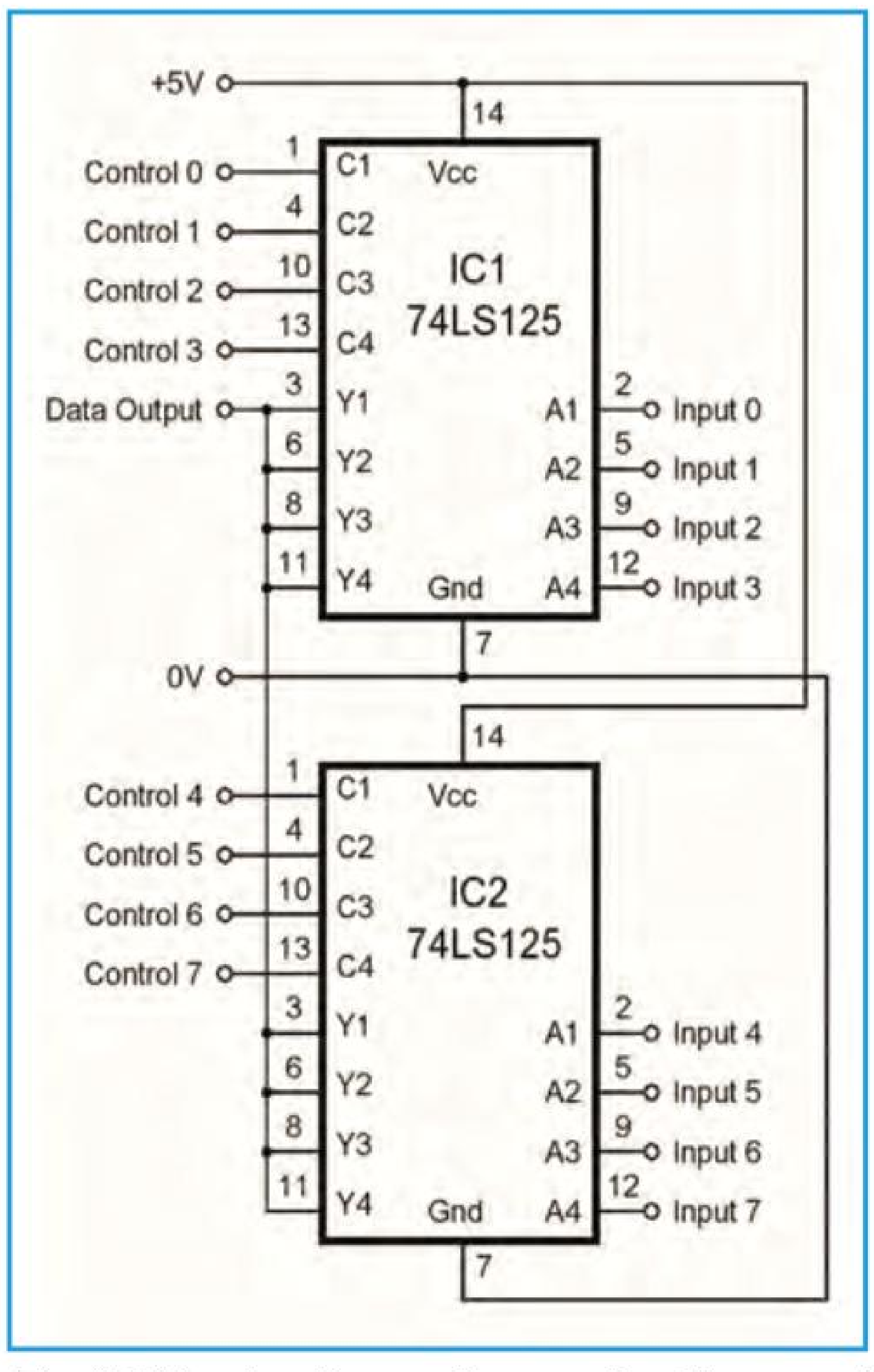
+5V
14
Vcc
IC1
74LS125
Control 0
Control 1
Control 2
Control 3
Data Output
1
4
10
13
3
6
8
11
C1
C2
C3
C4
Y1
Y2
Y3
Y4
A1
A2
A3
A4
Gnd
2
5
9
12
Input 0
Input 1
Input 2
Input 3
7
0V
14
Vcc
IC2
74LS125
Control 4
Control 5
Control 6
Control 7
Input 4
Input 5
Input 6
Input 7
7

Fig.4. This circuit uses three output lines and one input to provide individual monitoring of eight sources. It must be used in conjunction with the 3-to-8-line decoder circuit of Fig.1

Individual monitoring of several sensors can be accomplished using a system that is essentially the same as the auto-ranging setup outlined previously, but tristate buffers would be used instead of analogue switches. The circuit of Fig.4 can be used in conjunction with a 3-to-8-line decoder to enable eight sensors to be individually monitored using one input line and three outputs. In other words, four lines of a computer port are used to give individual monitoring of eight inputs.

The eight tristate buffers are provided by two 74LS125 chips, and the buffers are of the non-inverting variety. The four inputs of each chip are A1 to A4, the outputs are Y1 to Y4, and C1 to C4 are the control inputs. This application requires a separate control input for each buffer, so something like a 74LS244 octal tristate buffer cannot be used. All eight of the Y outputs are connected together and monitored by a single input of the computer port. The control inputs are individually controlled by the eight outputs of the 3-to-8-line decoder, and the 74LS138 decoder circuit of Fig.1 is suitable. Taking a control input of a buffer low activates its output stage, and it then operates as a normal logic buffer stage. A high control signal sends the output of the buffer into its high impedance state and it then goes to the state dictated by whichever of the outputs is active. The decoder circuit has one output low and all the others high, which gives the required action with one buffer active and the other seven switched off.

In order to read the state of a sensor, all the controlling software has to do is place the appropriate binary pattern on the three output lines of the port, and then read the state of the sensor on the input line. In a practical application, the software would probably cycle repeatedly through the eight binary patterns and monitor the sensors continuously. However, this method does give random access to the sensors, making it possible to check the state of any sensor whenever necessary.

There should be no problems if this basic scheme of things was expanded to include four 74LS125 buffers controlled by a 4-to-16-line decoder. This would enable sixteen sensors to be monitored using four outputs and one input line. A total of five lines on a computer port would then provide individual monitoring of sixteen sensors. As before, random access would be provided, and any sensor could be read on demand.

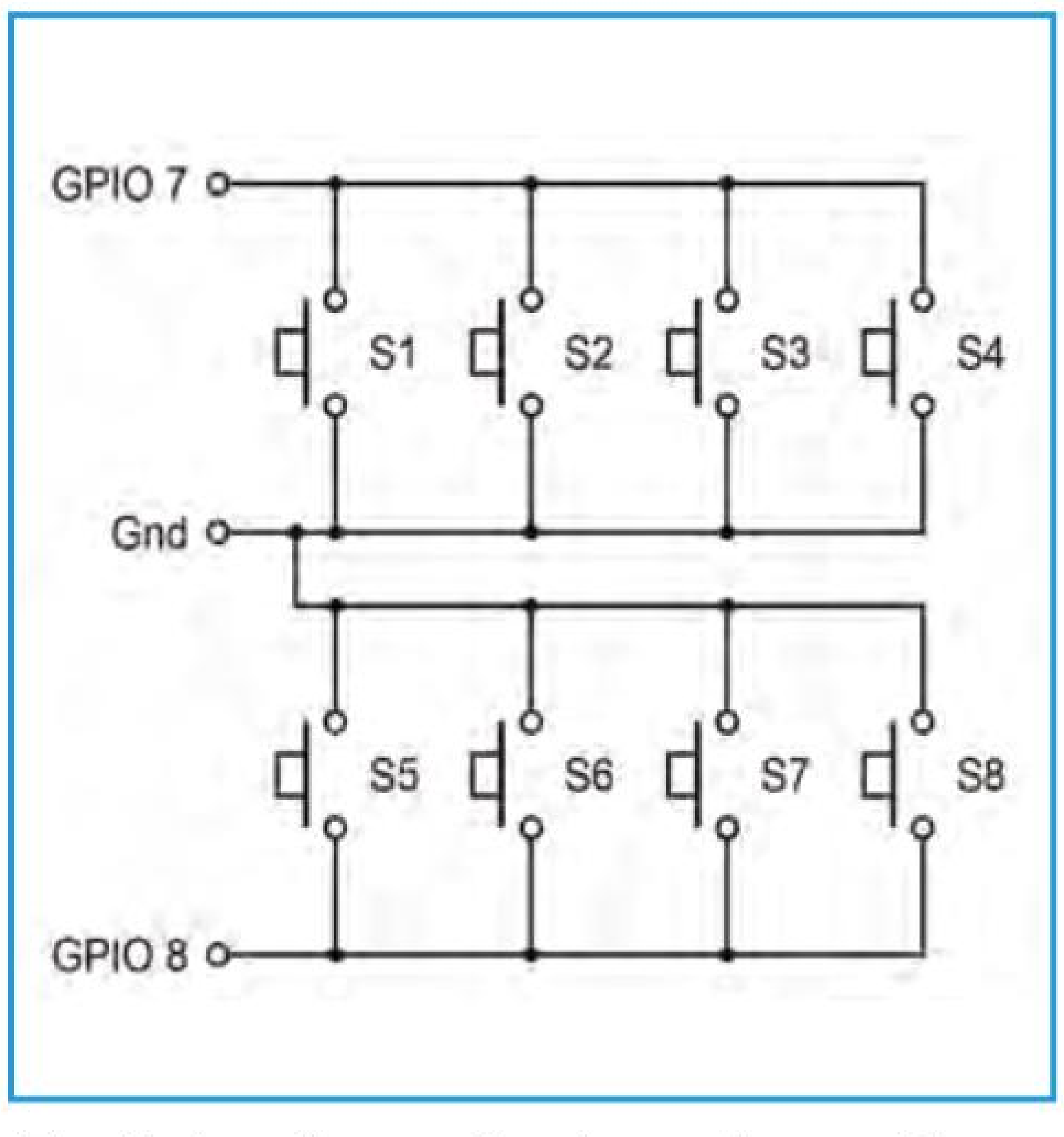
GPIO 7
S1
S2
S3
S4
Gnd
S5
S6
S7
S8
GPIO 8

Fig.5. A quiz monitor based on a Raspberry Pi needs nothing more than the switches and connecting wires. GPIO 7 and GPIO 8 of the GPIO port must be set as inputs having built-in pull-up resistors

A switch in time

With the GPIO inputs of a Raspberry Pi computer it is not necessary to use any gating in order to monitor several switch type sensors from a single input. The same is true when monitoring manually operated switches, such as in a quiz monitor application. The circuit of Fig.5 is all that would be needed in order to provide a quiz monitor for two teams of four players. The GPIO 7 and GPIO 8 lines would be set to operate as inputs using integral pull-up resistors. Operating any switch in each bank would pull the relevant input low and trigger the monitoring software.

There are so many input/output lines on the GPIO port that something more elaborate could easily be accommodated. Up to eighteen teams with any number of players per team could be handled! Alternatively you could have something like four teams of four players, with each of the sixteen switches connected to a different input of the GPIO port. The software could then detect which team had 'buzzed' first, and which player in that team had operated their switch.

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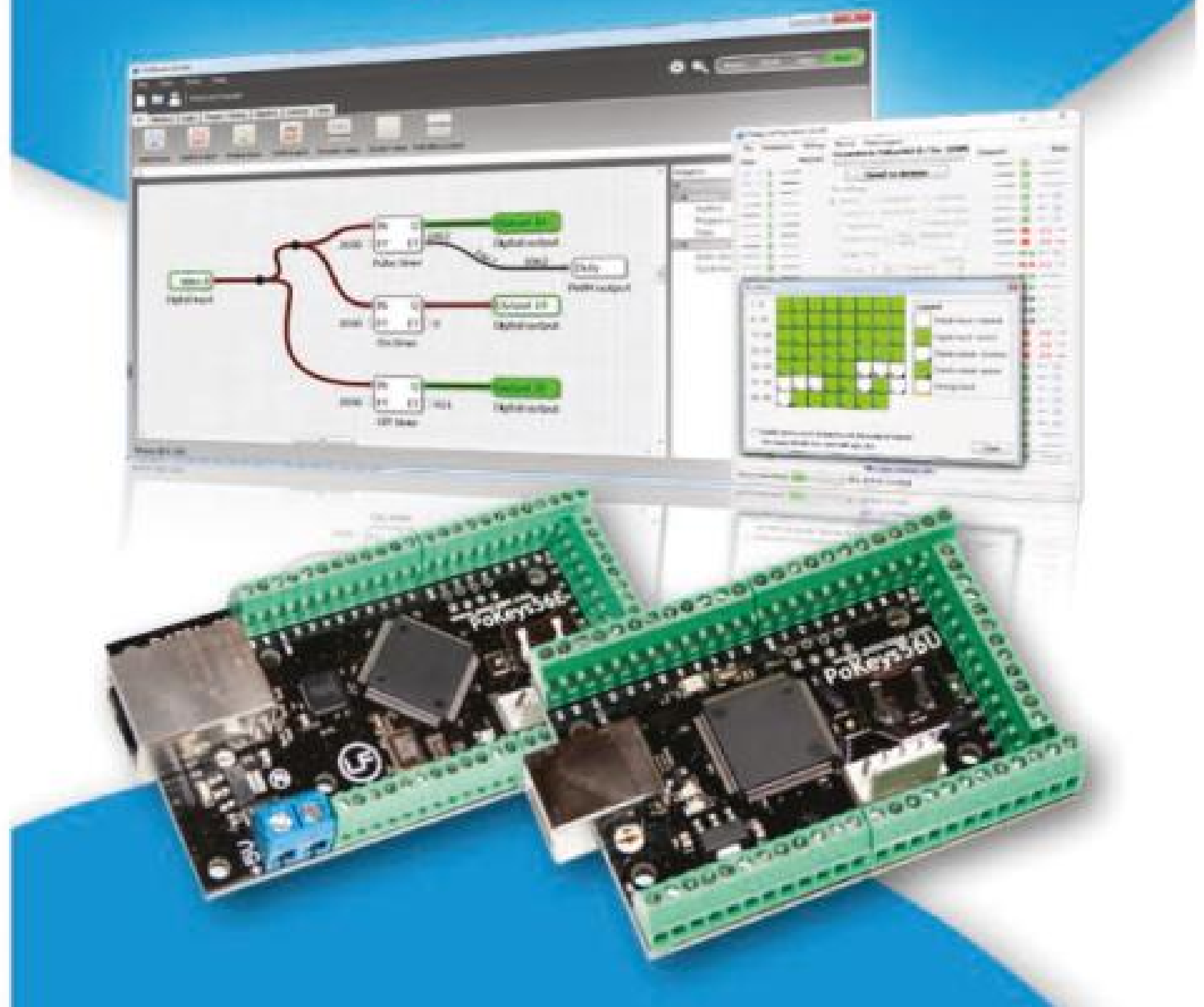

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BY IAN BELL

State-variable filters

THE following question about state-variable filters was posted by ***atferrari*** on the *EPE Chat Zones* forum. He refers to two circuits, but we will concentrate on one of these, which is the classic four-op-amp state-variable filter. We will also look at the more basic three-op-amp circuit on which it is based.

Universal state-variable filters. I've lost the magazine where these two circuits (Fig.1) were shown. I recall that in both, the formulas to calculate Q and band-pass gain were simple relations between two resistors. Could anyone tell them for A and B? Gracias for any help.

State-variable design

The state-variable filter is one of a number of filter circuit structures which use three or four op amps (the biquad is another example). The name 'state-variable filter' comes from the mathematical theory of state space. State-space theory is used to model (mathematically represent) real physical systems using differential equations and is often applied to control systems. Filters circuits are a classic example of the use of state-space models.

The state-variable filter contains two integrator circuits (implemented by the op amps with feedback capacitors C_1 and C_2 in Fig.1), whose outputs are scaled and summed with the input signal. This function can be directly related to a system as represented by state-space equations. The circuit can be regarded as an analogue computer calculating the response of a mechanical system with comparable state equations. Indeed, circuits like this were used in this way before the days of powerful digital computers. Fortunately for anyone who has not studied calculus (or has forgotten it) you don't have to understand state-space theory to make use of state-variable filters.

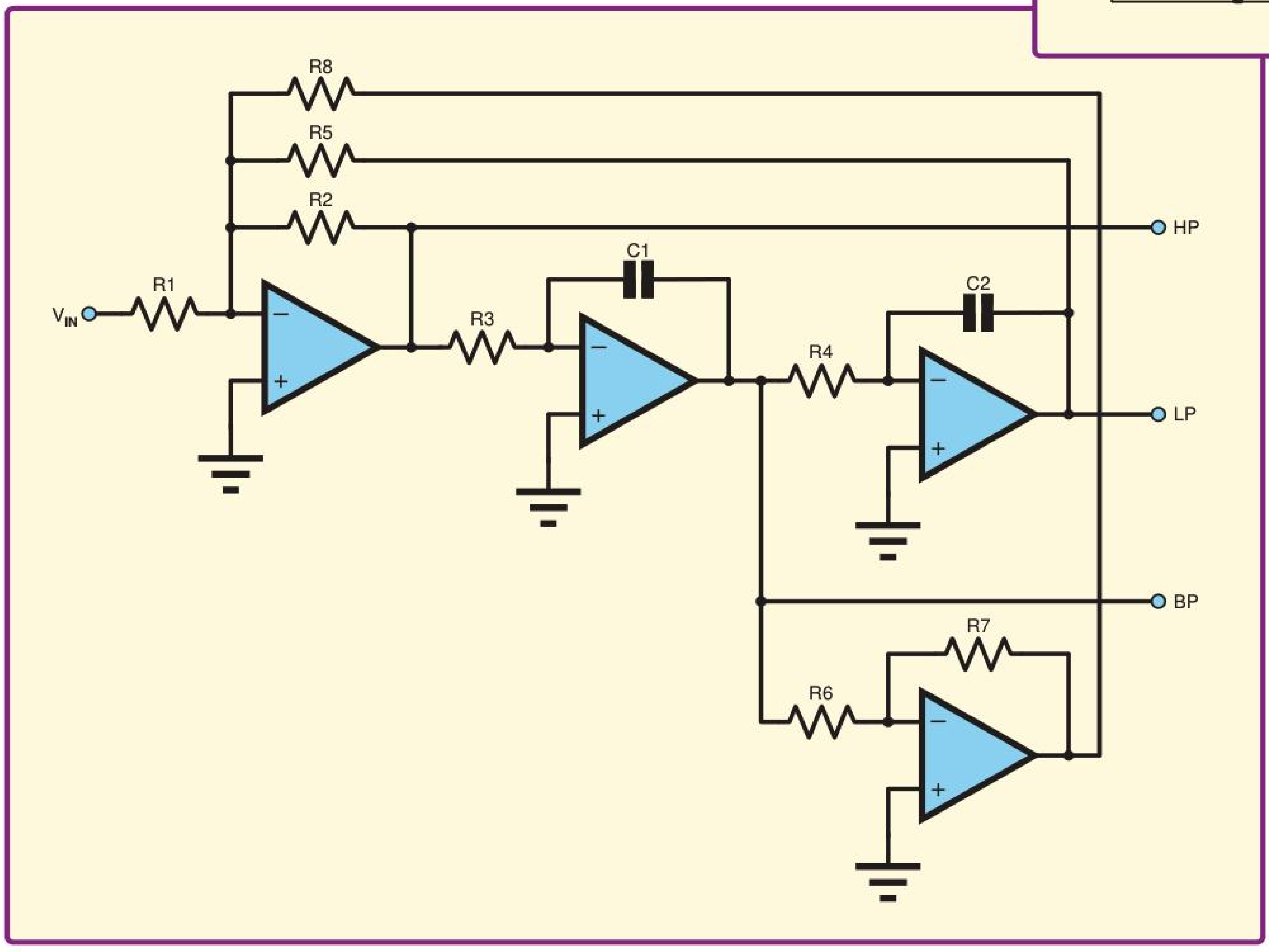


Fig.1. ***Atferrari's*** filter circuit

Before looking at the state-variable filter circuit in more detail we will start by defining some of the basic terminology associated with filters and relating this to the state-variable filter.

Filter types

Low-pass filters let low frequencies through and block high frequencies. High-pass filters let high frequencies through, but will also have an inherent upper frequency limit which will usually be higher than the frequencies in the signals of interest. Band-pass filters let a specific range of frequencies through. Band-stop filters reject a specific range of frequencies. A notch filter is a band-stop filter with a very narrow stop band, which can be useful for rejecting a specific unwanted frequency. The graphs in Fig.2 illustrate ideal filter responses.

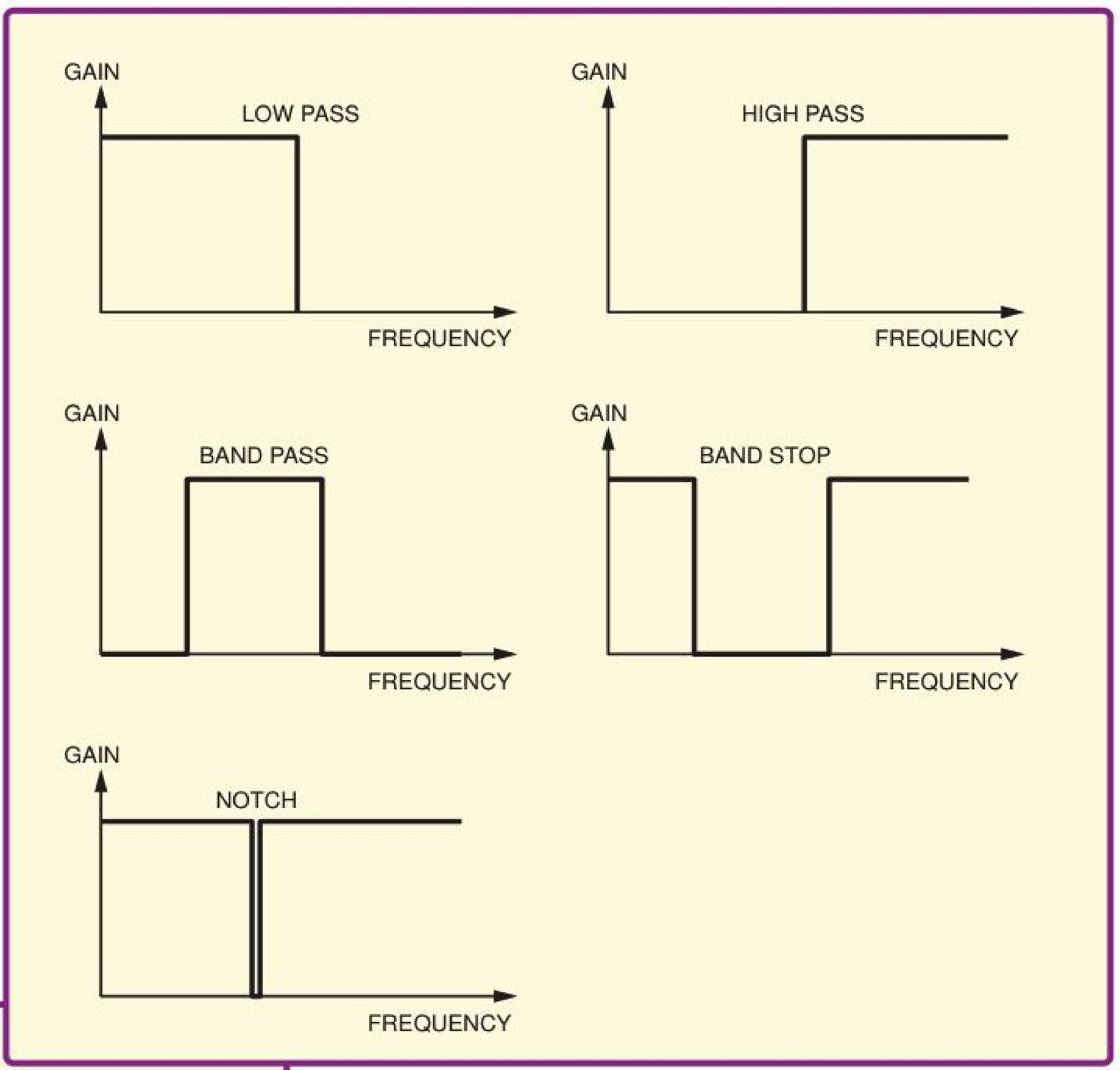


Fig.2. Ideal filter responses

One important feature of the state-variable filter is that it can act as a low-pass, high-pass or band-pass filter depending on which signal is taken as the output. It can also be used to produce notch filters.

For an ideal filter, the transition from pass band to stop band occurs at a single frequency. For real filters the transition from pass band to stop band occurs over a range of frequencies (see Fig.3). Thus we need to specify exactly what we mean by 'cut-off frequency'. The cut-off is usually defined as the frequency where the filter's gain is –3dB with respect to the pass-band gain (maximum gain in the pass band). This is the point where

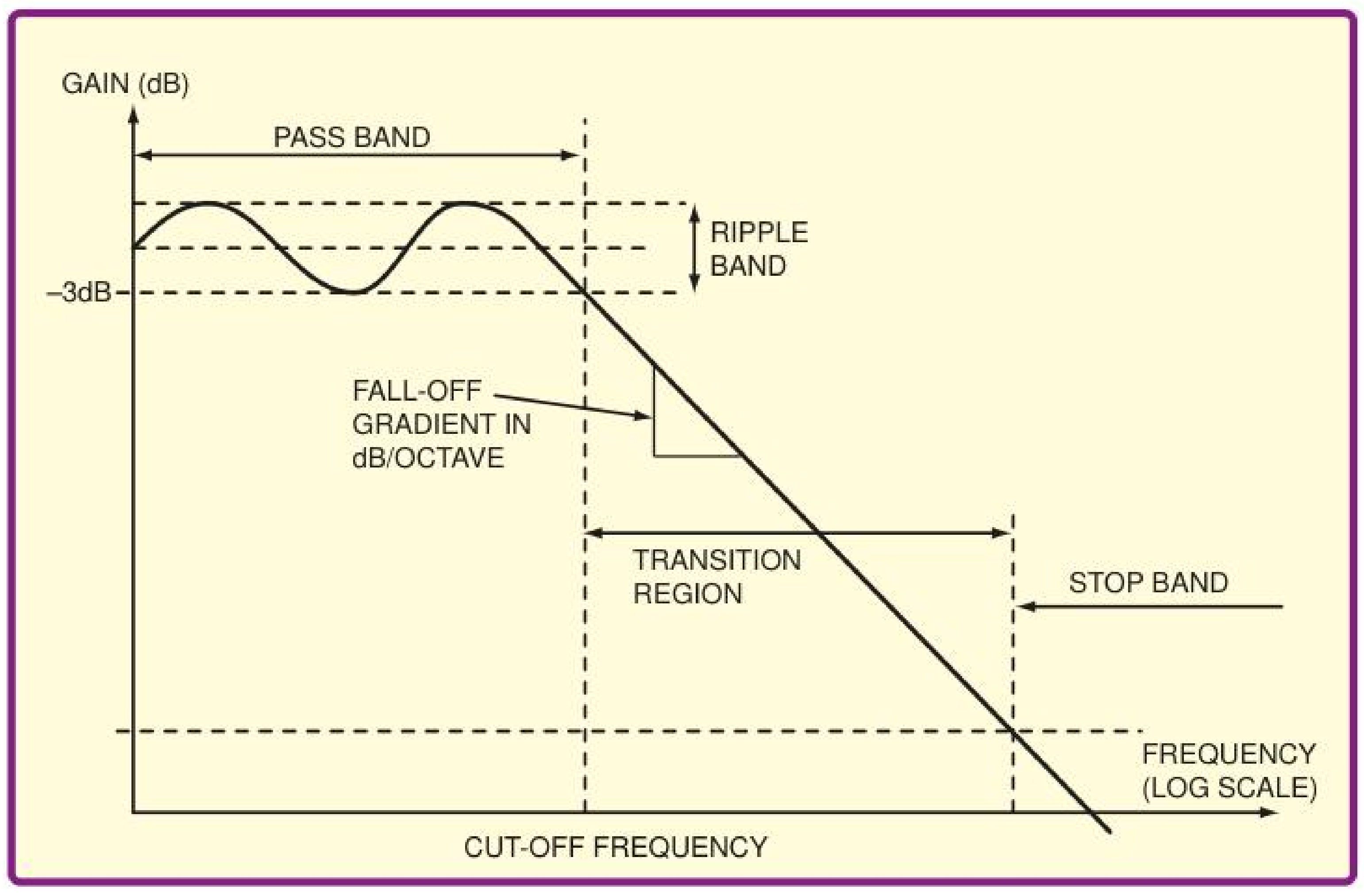


Fig.3. Frequency domain response

the output signal has half the maximum power it has in the pass band. The cut-off frequency of the state-variable filter is determined by the component values of the two integrators (C_1, R_3, C_2 and R_4 in Fig.1).

Frequency response

The vertical axis on filter frequency response graphs (for example Fig.3), shows filter gain, or attenuation, and is usually expressed in decibels, which is a logarithmic scale. For a gain A (as a straight number) the value in decibels is $20 \times \log_{10}(A)$ dB. The factor of 20 which is used here applies to signal voltage or current; a factor of 10 is used for expressing signal power in decibels. Circuit equations for the gain of filters, such as the ones requested by ***atferrari***, which we will look at later, give the pass-band gain, A, directly rather than a decibel value.

The horizontal (frequency) axis of the graph is also usually logarithmic (eg, the scale is typically marked 1Hz, 10Hz, 100Hz, 1kHz etc at even intervals). These times-ten steps are referred to as 'decades'.

The slope of the frequency response in the transition region/stop band (see Fig.3) indicates how quickly the filter's gain drops as the frequency moves away from cut-off into the stop band. For many filters, at frequencies well into the stop band, the response decreases as a straight line when plotted on a graph of decibels against log frequency (this is the case with the state-variable filters described here). The slope is measured in dB per decade and is called the 'fall-off' or 'roll-off'. The roll-off may be different (and changing) near the cut-off, but the term usually refers to ultimate roll-off, at frequencies sufficiently far from the cut-off, unless otherwise stated.

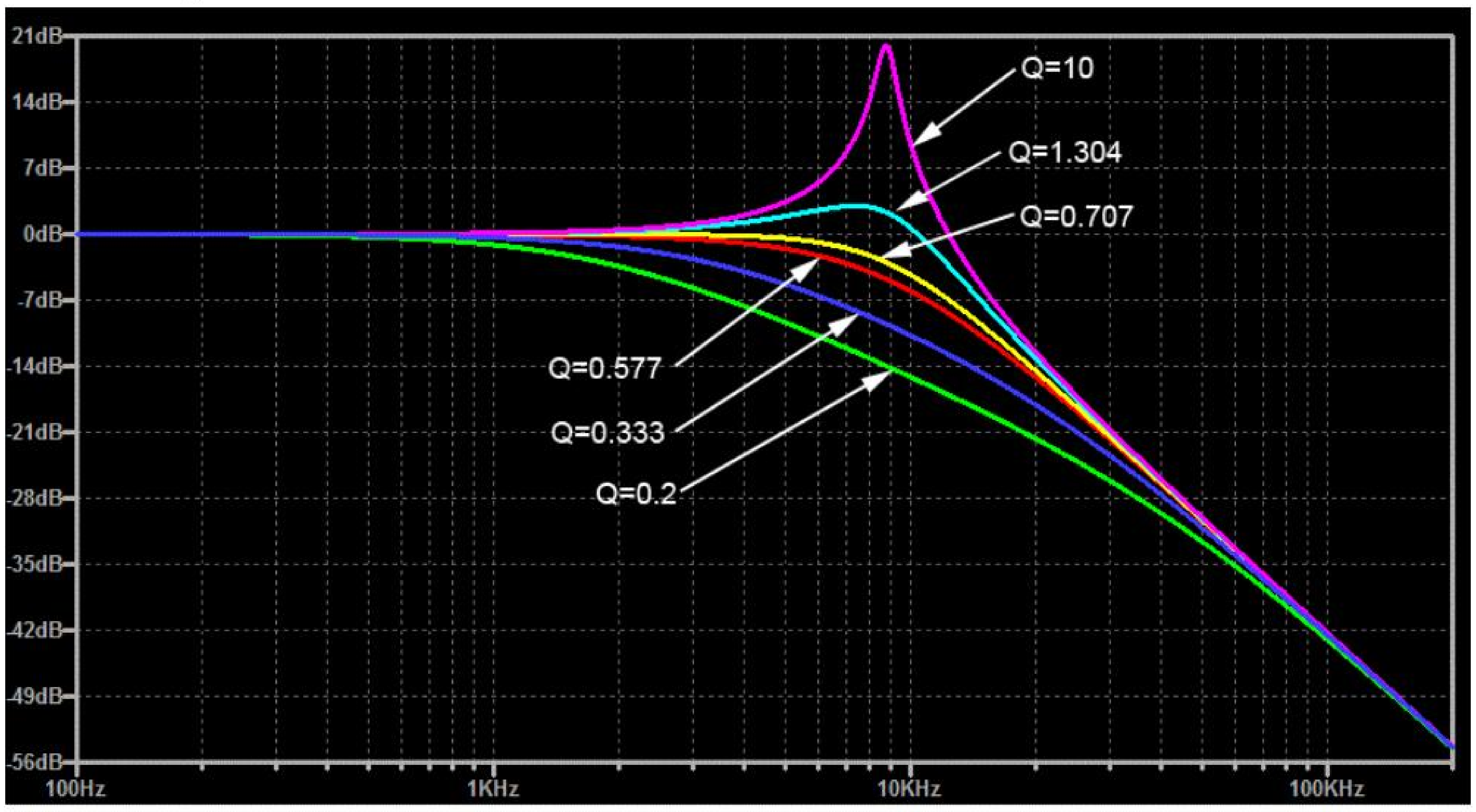


Fig.4. Low-pass response for various Q values

The ultimate roll-off is determined by the order of the filter; the higher the order the faster the fall-off. A single *RC* filter is first order and falls off at 20dB/decade. An N-th order filter rolls off at 20×N 20dB/decade. The state-variable filter shown in Fig.1 is second order.

Q is the quality factor of a filter. We discussed *Q* a few months ago in the context of *RLC* low-pass filters. Fig.4 shows the response of low-pass filters with various *Q* factors. Typically for low-pass filters we use relatively low *Q* values because high *Q* values result in a sharp peak around the cut-off frequency. Normally we want a low-pass filter to have a reasonably flat pass-band response and a smooth transition into the stop band. The situation is the same for high-pass filters.

For low-pass filters the term damping ($d=1/Q$) is sometimes used instead of *Q*, as it is perhaps more intuitive. Higher damping (lower *Q*) results in a slower, smoother transition from pass band to stop band and also avoids ringing (oscillation) when a rapidly changing step input is applied to the filter.

For band-pass filters the definition of *Q* factor may seem more directly relevant. *Q* is the ratio of bandwidth relative to centre frequency. If a band-pass filter has a centre frequency of f_0 and a bandwidth of f_b the *Q* factor is given by $Q = f_0/f_b$ there is often a demand for much higher *Q* values in band-pass filters than low-pass and high-pass. *Q* values in the range of 10s to 100s can be achieved with op amp-based circuits. Fig.5 shows a number of second-order band-pass filter frequency responses. These examples have the same centre frequency and the same gain at the centre frequency, but different *Q* values. It can be seen that filters with high *Q* values have narrower pass bands.

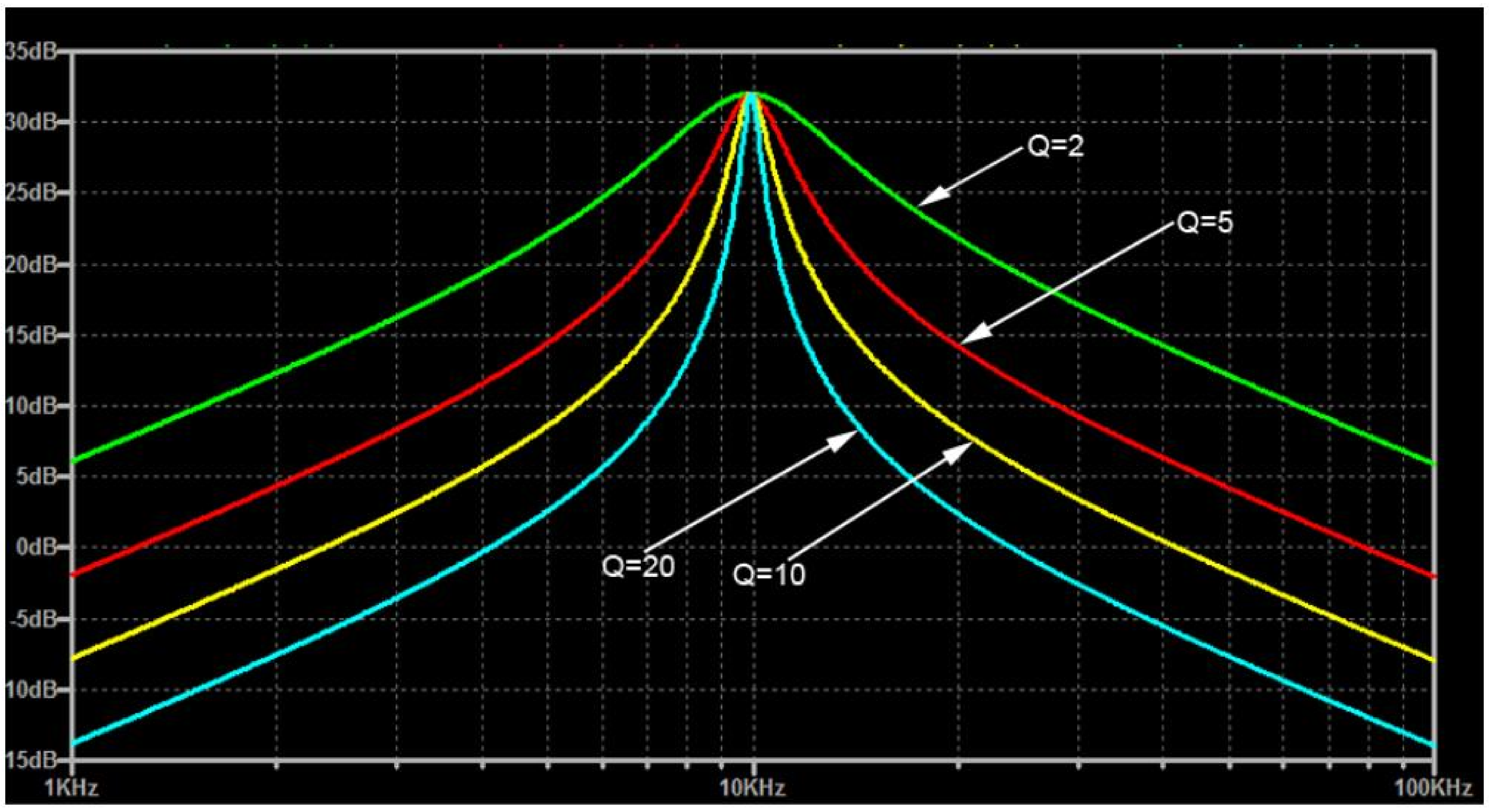


Fig.5. Band-pass response for various Q values

The state-variable circuit in Fig.1 is a second-order filter and uses four op amps; however, it is possible to make a second-order filter with just one op amp. A well known example is the Sallen and Key filter, for which a low-pass version is shown in Fig.6, which we have discussed in previous *Circuit Surgery* articles. The Sallen and Key is not often the best choice for band-pass filters, but other single-op-amp band-pass filters are available. So why use four op amps when one might do?

State-variable filter advantages

One advantage is that the state-variable filter has three outputs which provide low-pass, band-pass and high-pass responses, which makes it more versatile, allowing easy switching between responses, including under electronic control, although this feature may not be so important if only one type of filter is needed.

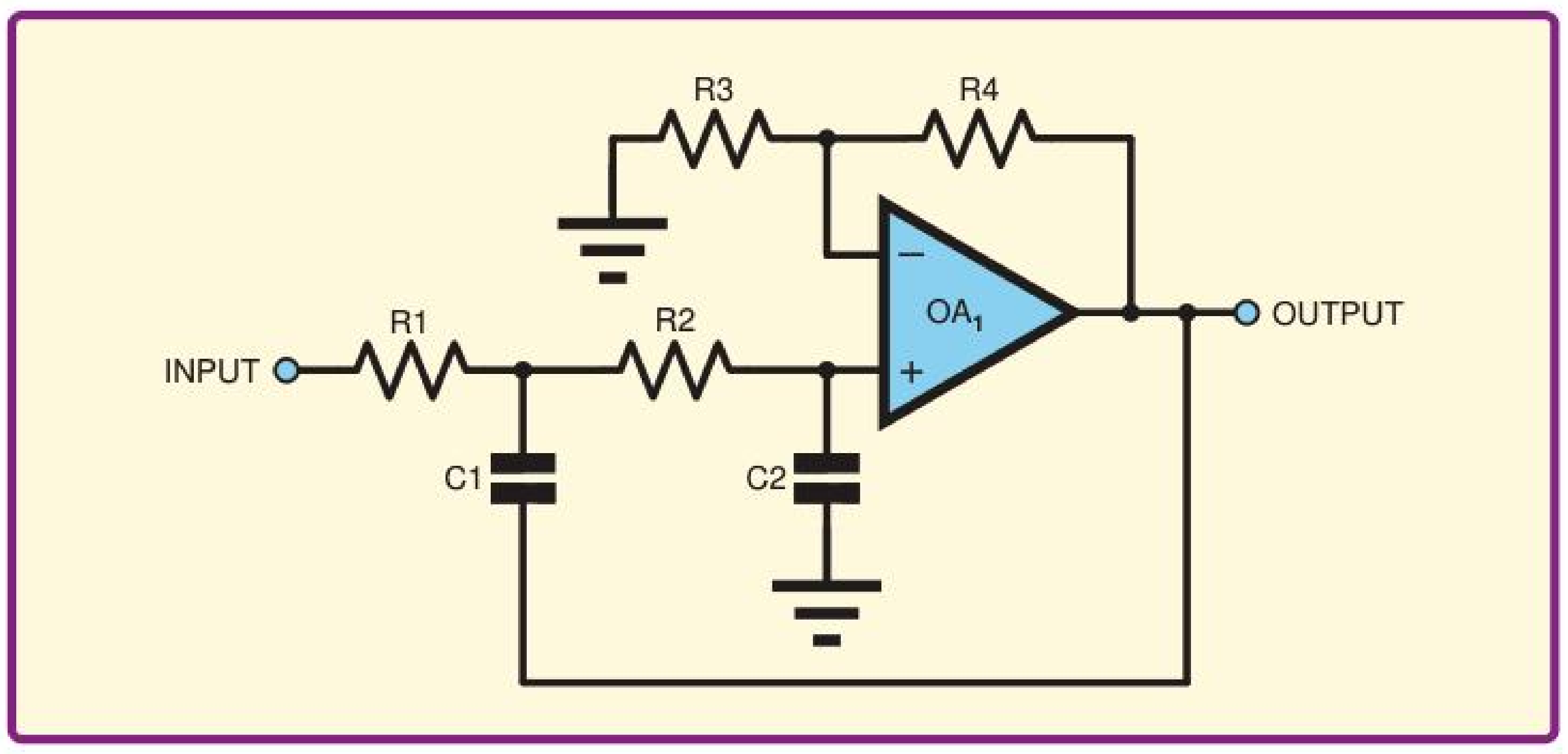


Fig.6. Second-order Sallen and Key low-pass filter

The first key advantage of the state-variable filter over a single op amp circuit is that it provides more independent control over its parameters (*frequency*, *gain* and *Q*). Typically, the resistors which control frequency in a single op amp filter circuit also affect *Q*. In state-variable filters different resistors are used to change frequency and *Q*. This makes it easier to design filters with variable response, either controlled manually via a potentiometer or under electronic control using switches, digipots or other techniques. In both cases, of course, the capacitors also set the frequency.

The second key advantage of the state-variable filter is that much higher *Q* filters can be built than with a single op amp circuit. Single op amp band-pass filters are usually limited to practical maximum *Q* factors in the range 5 to 10. Above this, the circuits demands very high performance from the op amps and may exhibit stability issues. State-variable filters place lower performance demands on op amps to achieve a filter with the same *Q*.

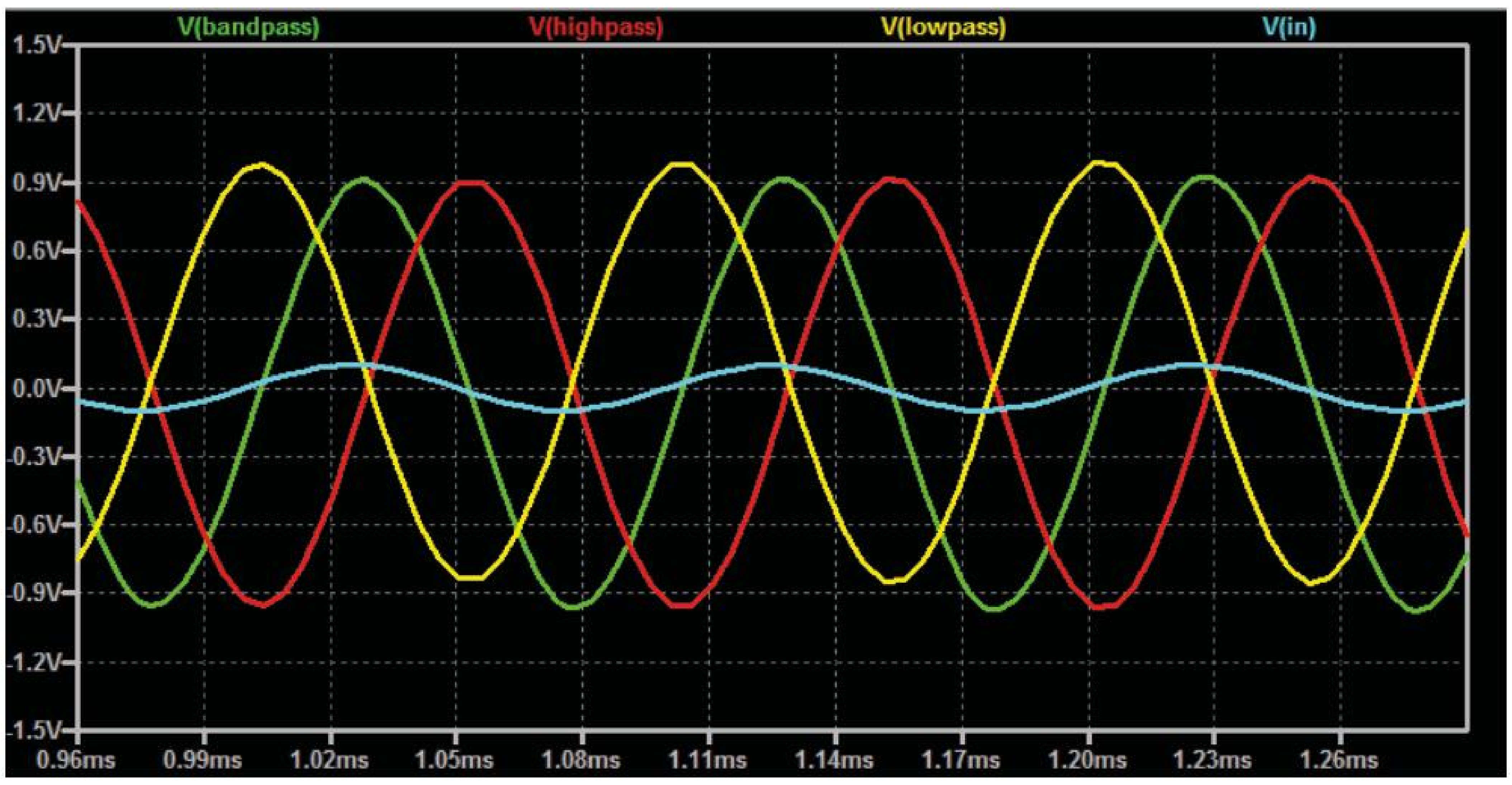


Fig.8. Waveforms from the circuit in Fig.6

Another advantage of the state-variable filter is that it is relatively less sensitive to component value variations (due to component tolerance, changes with temperature etc). This can be a significant problem in simpler circuits, particularly for higher *Q* values, or higher orders.

Simulation and design

The filter shown in Fig.7 is a basic three-op-amp state-variable figure on which ***atferrari's*** circuit is based. The schematic includes voltage sources for supplies and input signals to facilitate LTSpice simulation. The op amps shown (LT1817) have good high frequency performance, but many other op amps would be suitable.

As was previously mentioned, the state-variable filter has separate low-pass, band-pass and high-pass outputs. The low-pass and high-pass outputs are 180° out of phase with one another, as can be seen from the simulation output in Fig.8. The high-pass output is in phase with the input signal.

A simple procedure for setting up (tuning) the filter is to make all the resistors R_1, R_2, R_3, R_4, R_5 and R_7 have the same value, *R*, and the two capacitors the same value, *C*. A value of around 10k is probably about right for the resistors in many cases. The frequency of the filter is then set using:

$$f_0 = \frac{1}{2\pi RC}$$

So, if we choose *R*, *C* is given by

$$C = \frac{1}{2\pi f_0 R}$$

For example, for 10kHz with $R = 10\text{k}\Omega$ we get 1.6nF. If using $R = 10\text{k}\Omega$ gives a capacitor value which is too low or high (at relatively high or low frequencies) the value of *R* can be changed to give a more acceptable value. With R_1, R_2 and R_3 equal, the gain for the low-pass and high-pass outputs in the pass band is 1 (0dB).

The *Q* value of the filter and gain of the pass-band output is determined by R_6. For a required *Q*, R_6 is chosen using:

$$R_6 = R(3Q - 1)$$

For example, with $R = 10\text{k}\Omega$ and a required *Q* of 10, R_6 should be 290kΩ. The gain of the pass-band output at the centre frequency f_0 is equal to *Q* (10 in this case, which is 20dB). For a given R_6, and all other resistors of value *R*, the *Q* is given by:

$$Q = \frac{\left(\frac{R_6}{R} + 1\right)}{3}$$

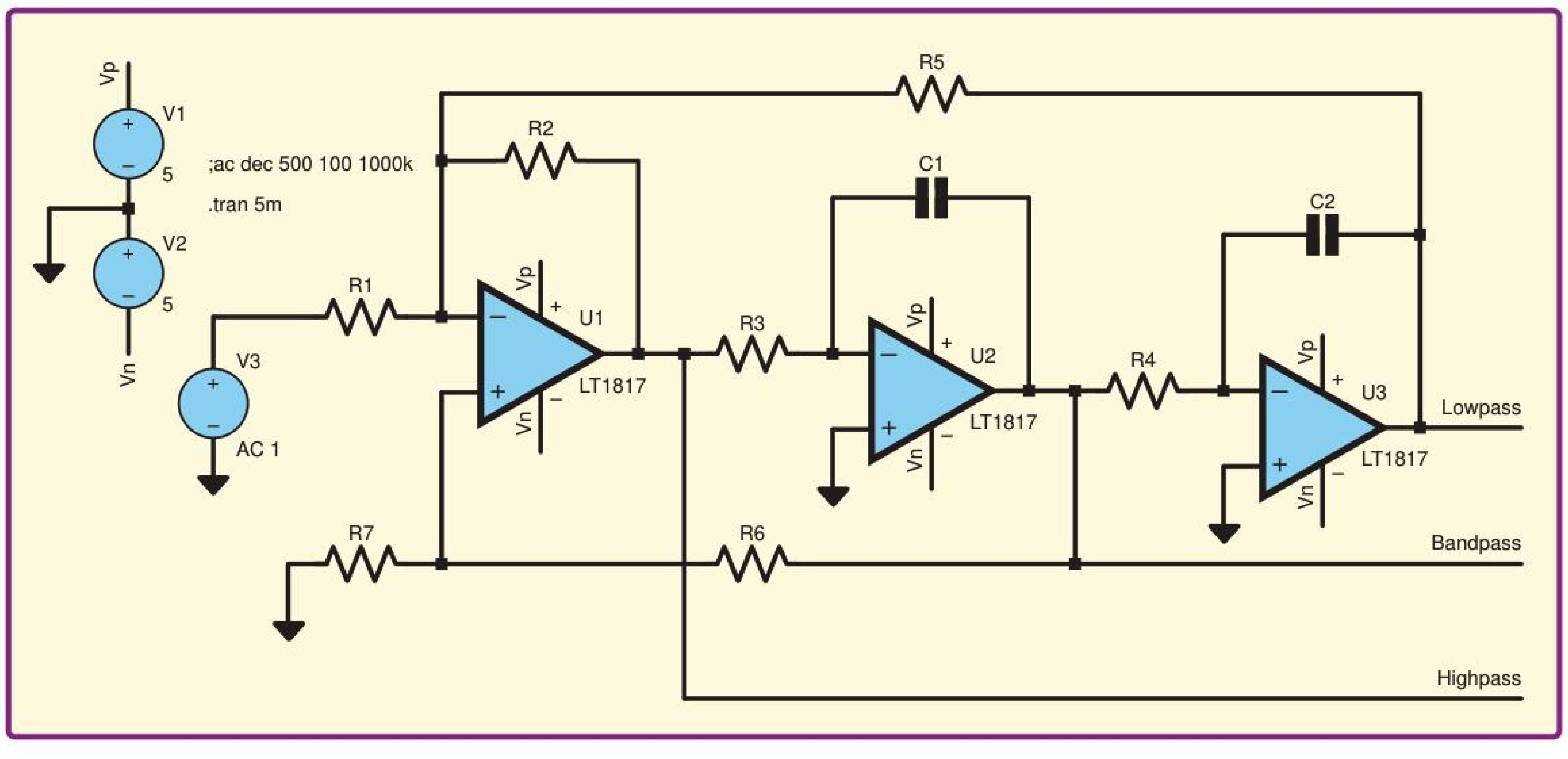


Fig.7 Basic state-variable filter

The circuit in Fig.7 allows the frequency and *Q* factor to be set independently; however, the gain of the band-pass output is related to *Q* and cannot be independently set or controlled. The results of an LTspice frequency response simulation of the circuit in Fig.7, using the example values just calculated is shown in Fig.9. This confirms that the frequency and gain are as calculated.

Fig.10 shows a zoom-in on the band-pass plot for the example filter around the centre frequency, f_0, which can be seen to be close to the 10kHz designed value.

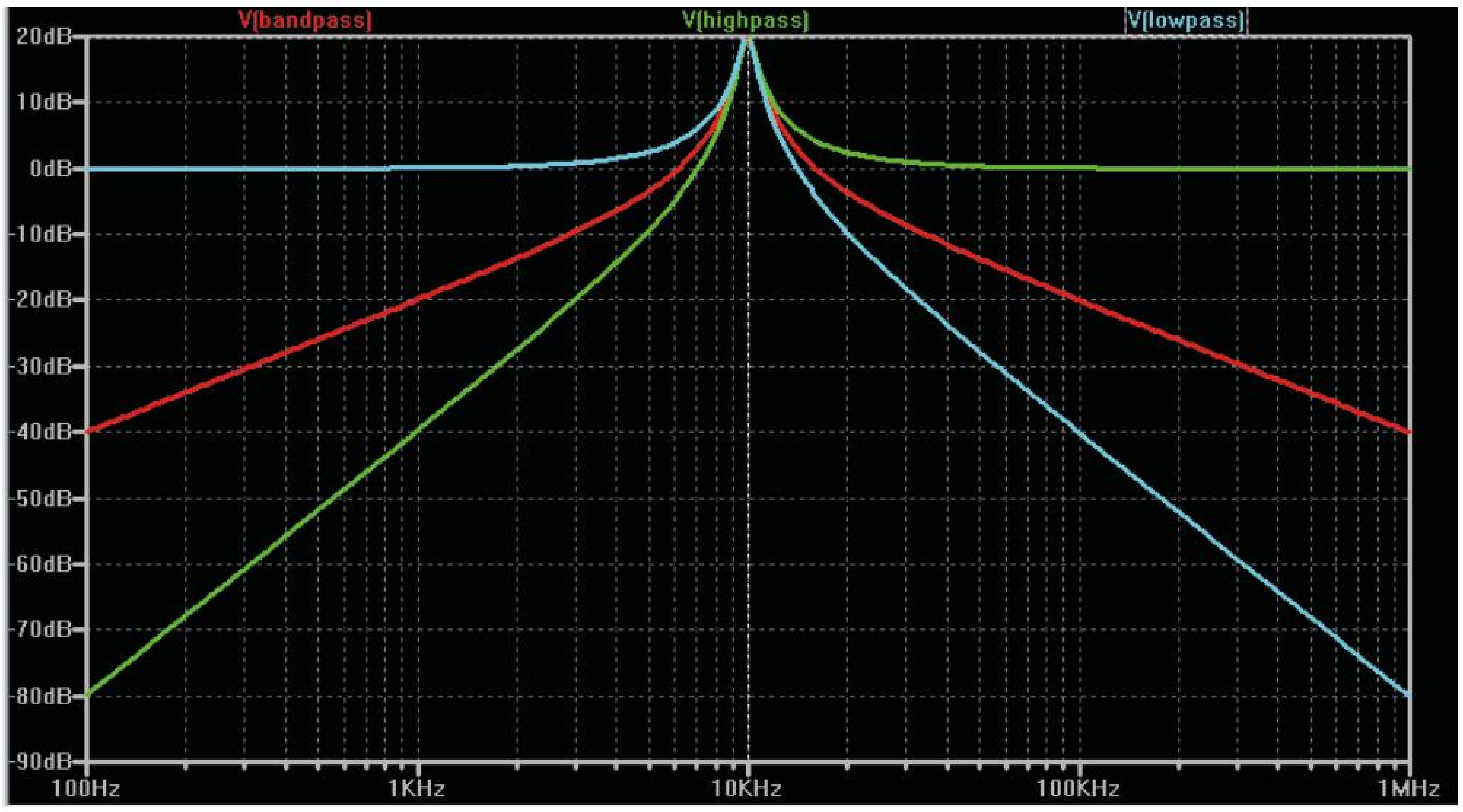


Fig.9. LTSpice simulated response of circuit shown in Fig.7

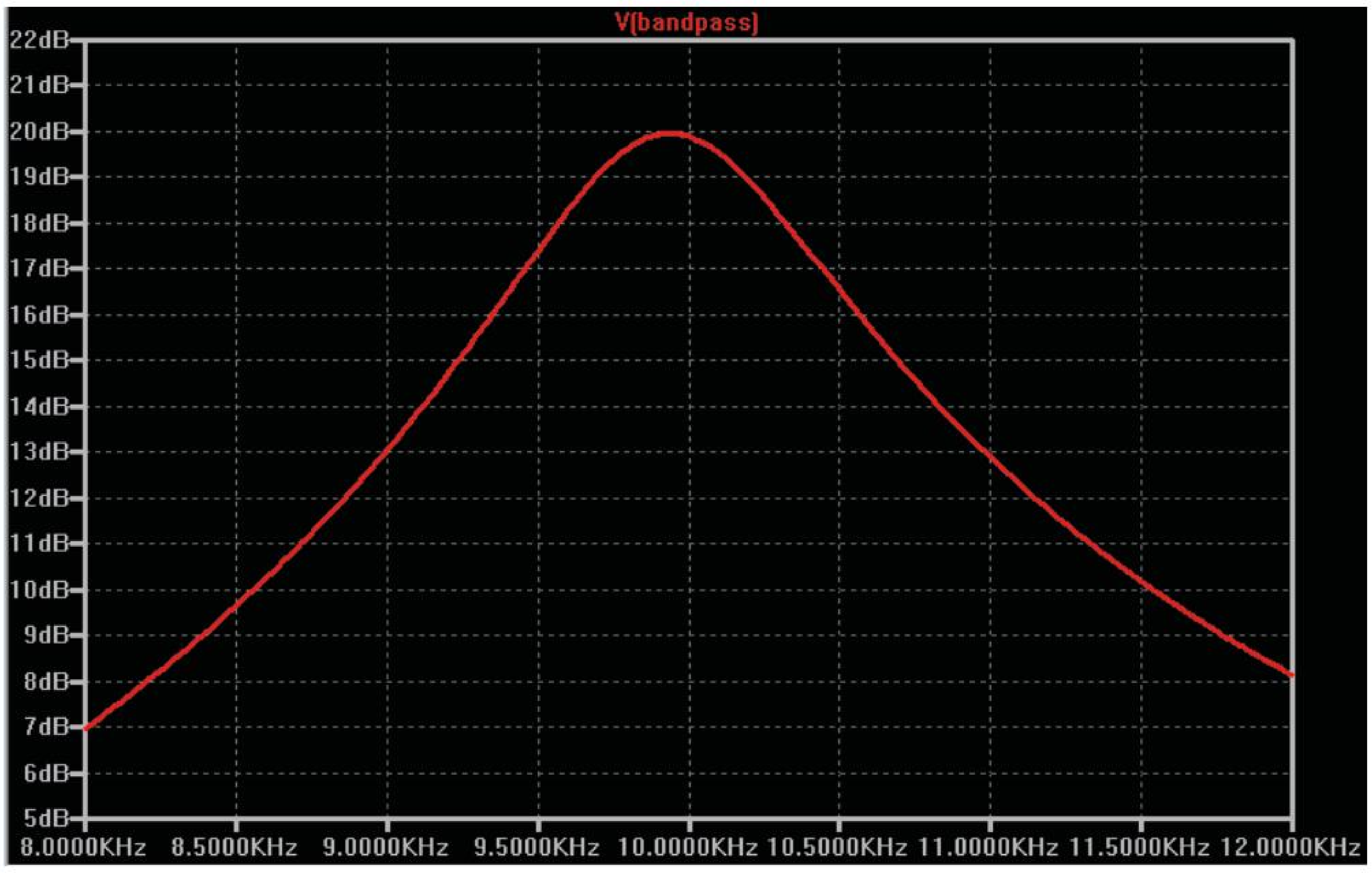


Fig.10. Zoom in on band-pass response from Fig.8

The centre frequency gain is 20dB as calculated above. The –3dB points are at 17dB (20-3) which occur at around 9.5kHz and 10.5kHz. The bandwidth is therefore 10.5 – 9.5 = 1kHz. The Q factor is f_0/f_b = 10kHz/1.0kHz = 10, again matching the designed value.

The circuit posted by atferrari has an additional op amp and allows the gain to be set independently of the Q factor. The circuit in Fig.11 is a version of the circuit in Fig.1 set up for LTSpice simulation in the same way as the circuit in Fig.7. The nodeset directive shown on the schematic helps the simulator find the DC initial conditions.

The four-op-amp state-variable filter replaces R_6 and R_7 with an op amp. Tuning this circuit is straightforward. First, in a similar way to the circuit in Fig.7 we make resistors R_2, R_5 and R_8 equal, with 10kΩ being a typical value. R_3 and R_4 also typically have the same value as R_2, R_5 and R_8, but may be varied to adjust the frequency. R_3 and R_4 have the same value. As before, the frequency is set by using:

$$f_0 = \frac{1}{2\pi RC} \quad \text{or} \quad C = \frac{1}{2\pi f_0 R}$$

where R is the value of R_3 and R_4, and C is the value of both C_1 and C_2. R_3 and R_4 can be a dual gang potentiometer if variable frequency is required.

The gain, A, is set by R_1 and given by:

$$A = \frac{R}{R_1} \quad \text{or} \quad R_1 = \frac{R}{A}$$

Where R is the value of R_2, R_5 and R_8. R can be a potentiometer if variable gain is required.

The Q factor is set using R_6 and R_7 using:

$$Q = \frac{R_6}{R_7}$$

Typically, R_7 has the same value, R, as R_2, R_5 and R_8, in which case R_6 is given by:

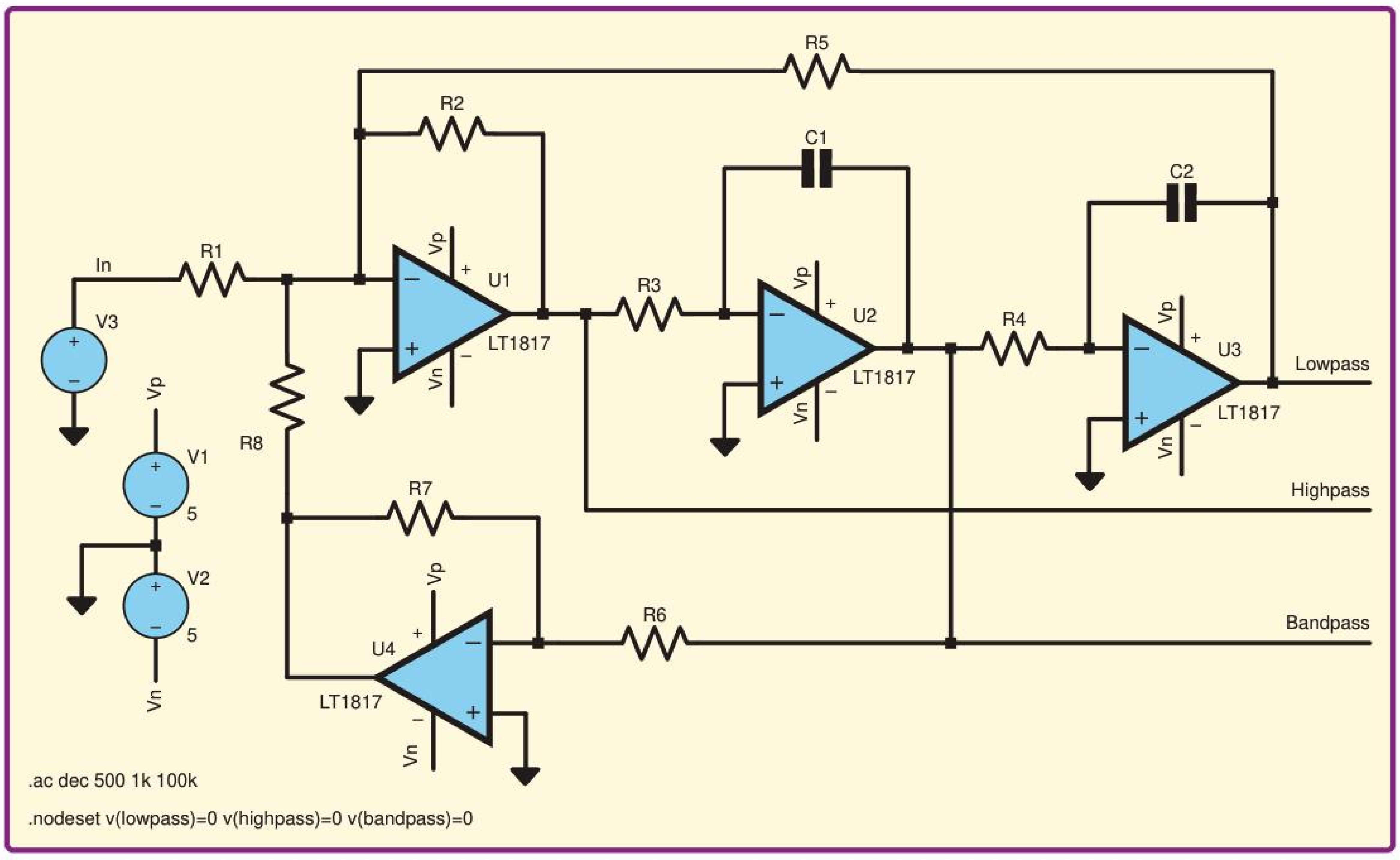
$$R_6 = RQ$$

R_6 can be a potentiometer used to vary Q.

Final considerations

A few further points are worth mentioning if high Q filters are required. It is best to use components which are as accurate and stable as possible (within budget constraints) and op amps with high gain-bandwidth products will generally provide circuits which perform better, although as has already been mentioned, the demands on component performance are relatively low in state-variable filters.

Like other filters, state-variable filters should be driven from a low impedance source. If this is not directly available a buffer circuit should be put between the source and filter input. High slew rate op amps will be needed if the filter has to handle signals at higher amplitudes and frequencies, this is true irrespective of the type of filter circuit used, as slew rate simply determines whether or not the op amp can change its output voltage fast enough to produce the required waveform.



```
.ac dec 500 1k 100k
.nodeset v(lowpass)=0 v(highpass)=0 v(bandpass)=0
```

Fig.11 Four-op-amp state variable filter

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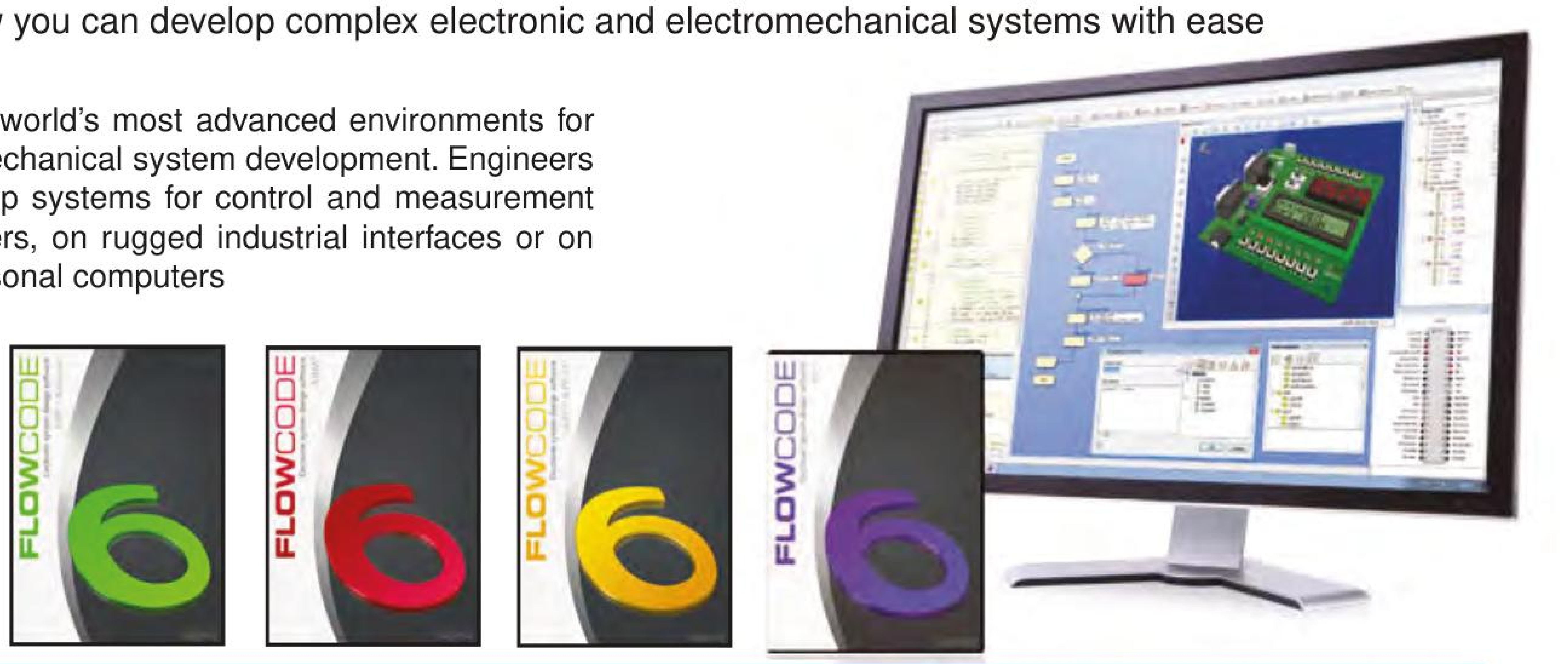

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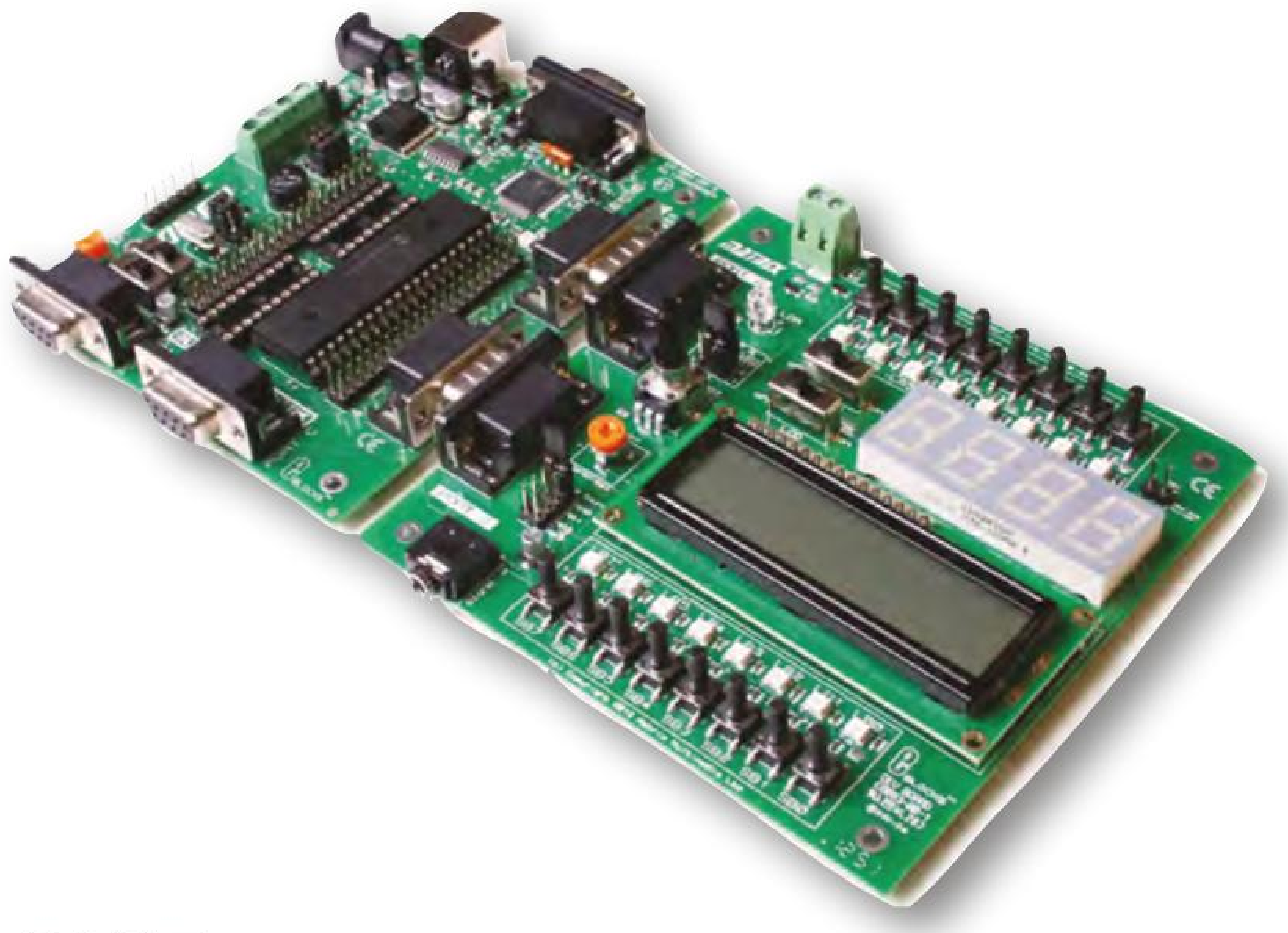

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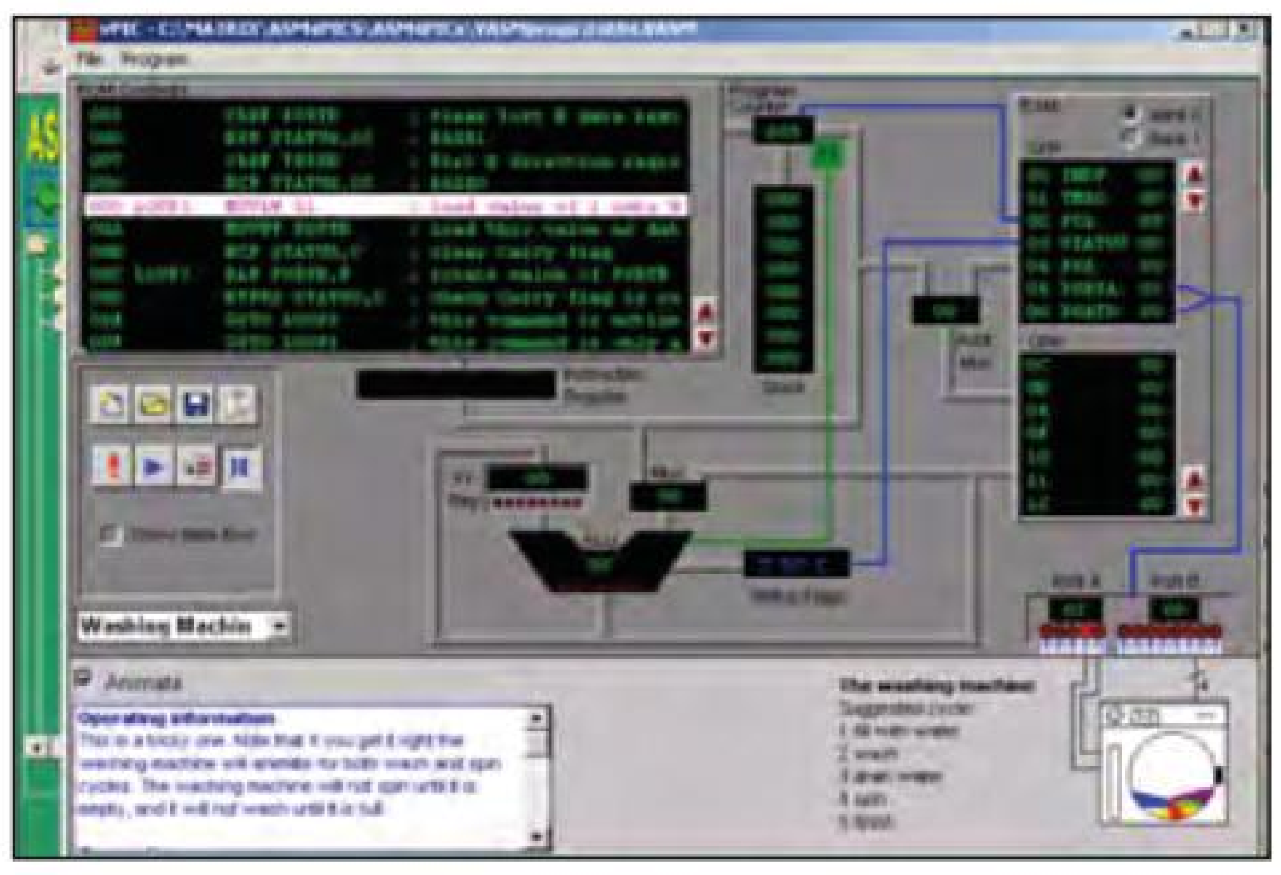

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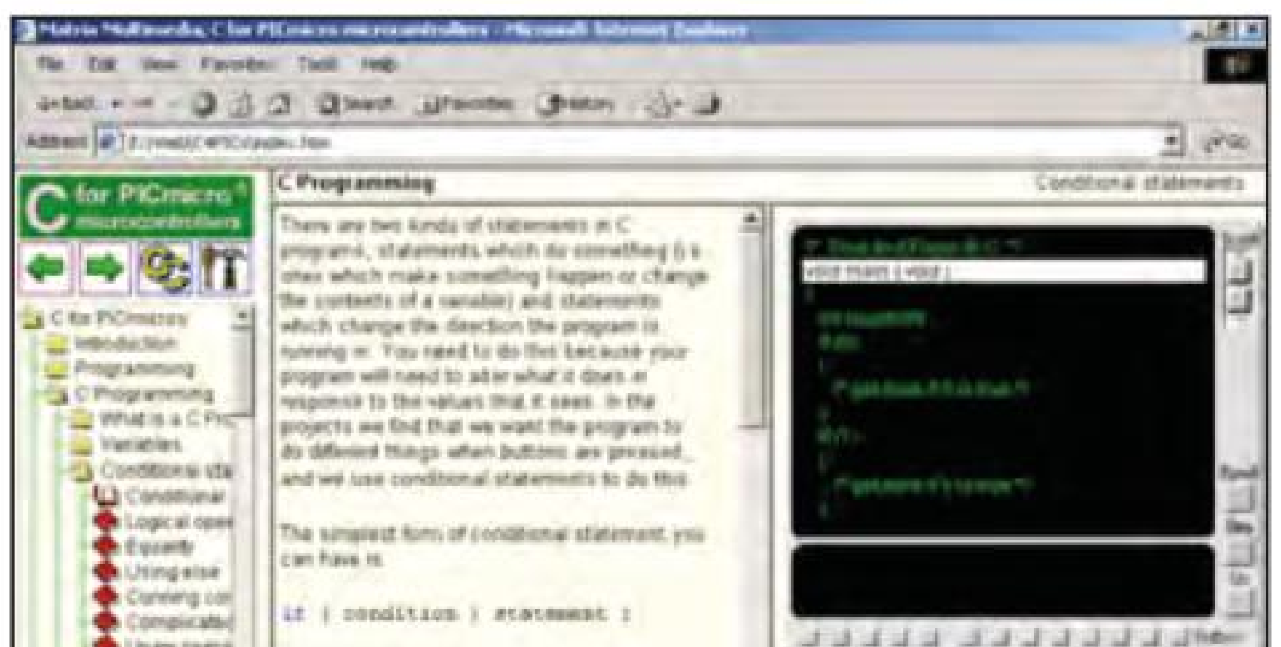

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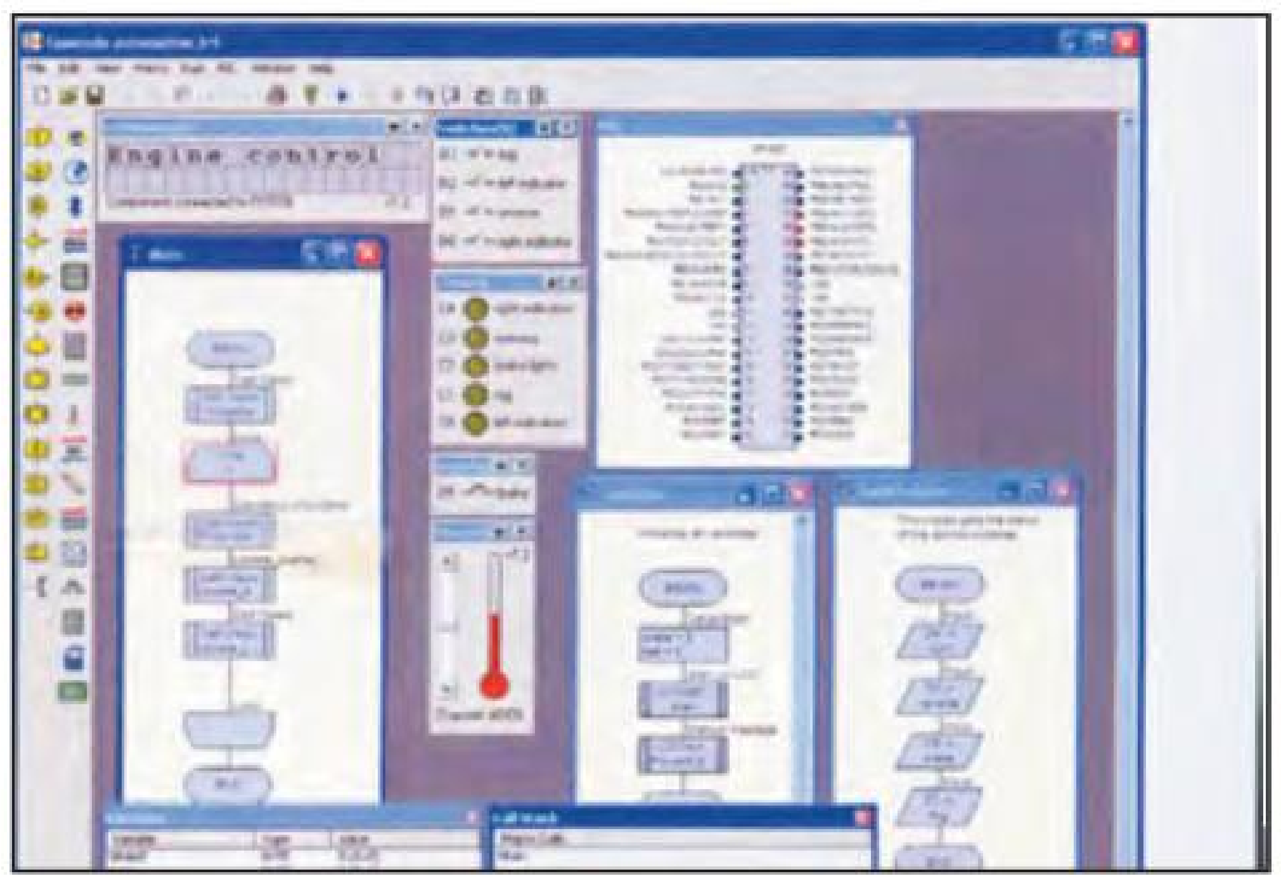

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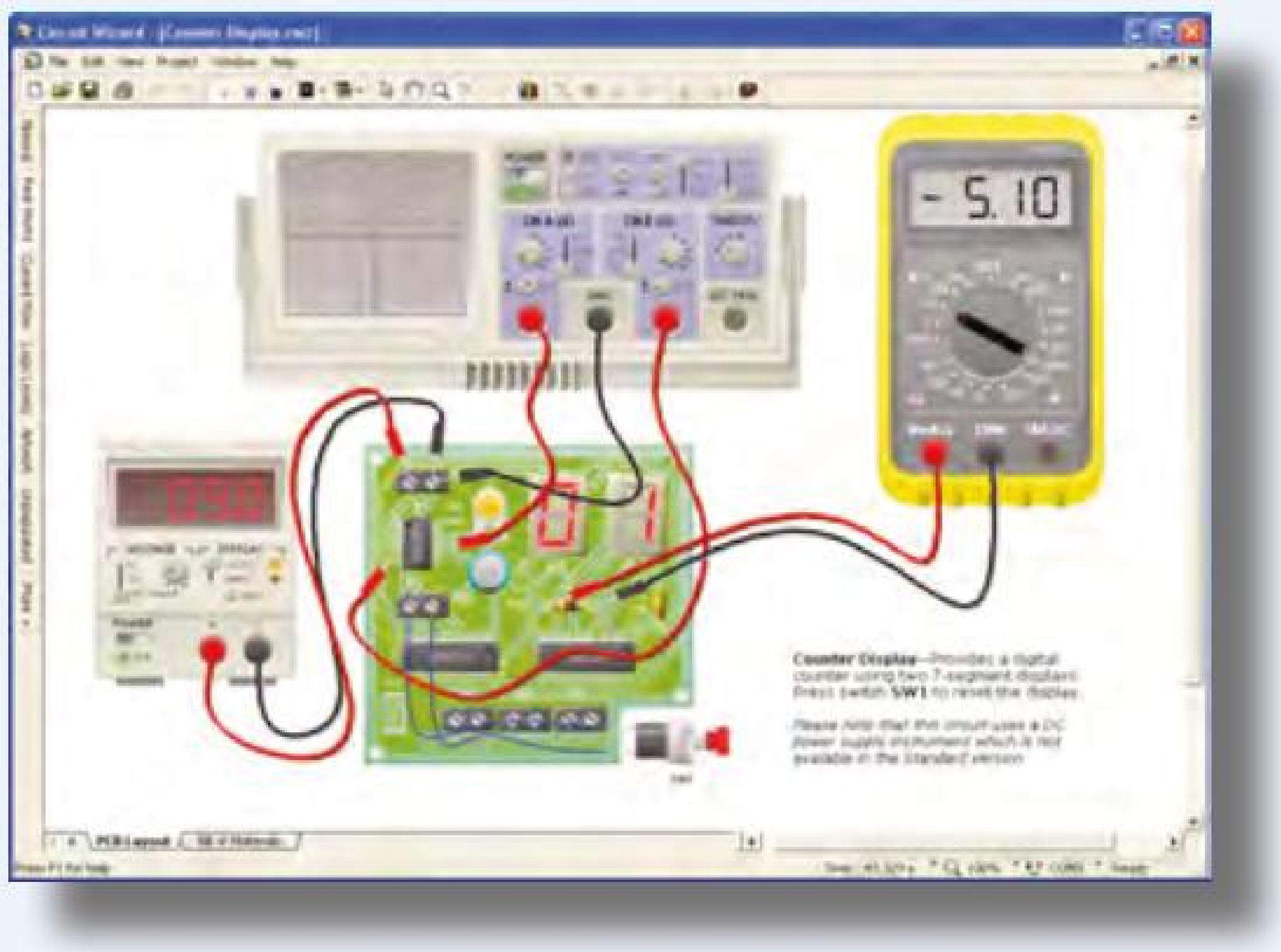

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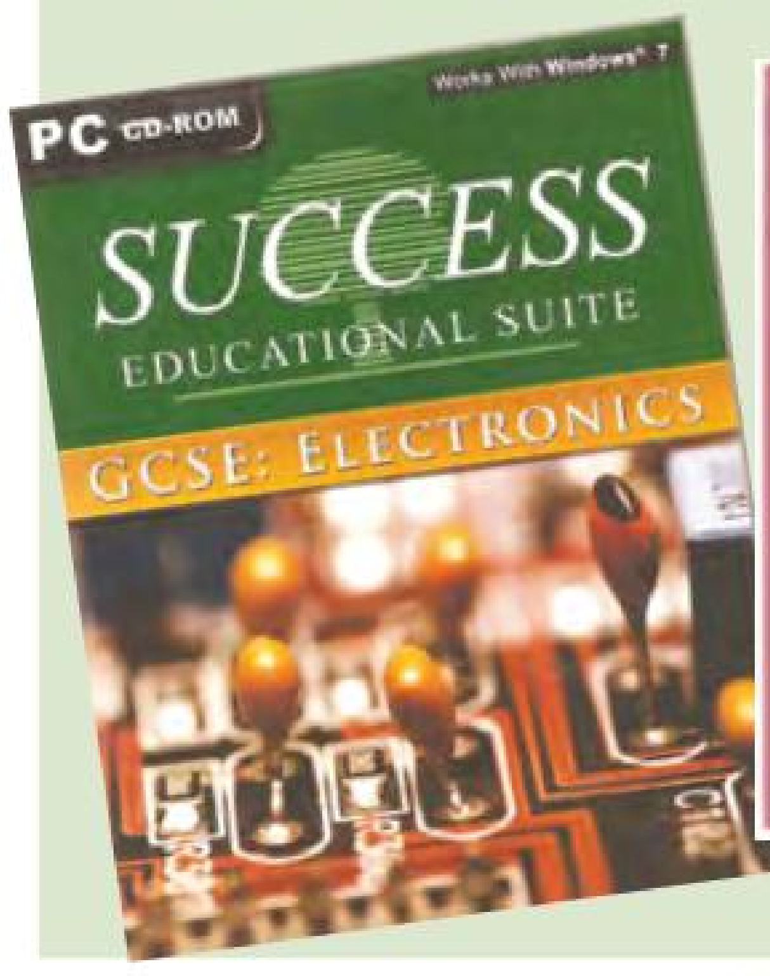

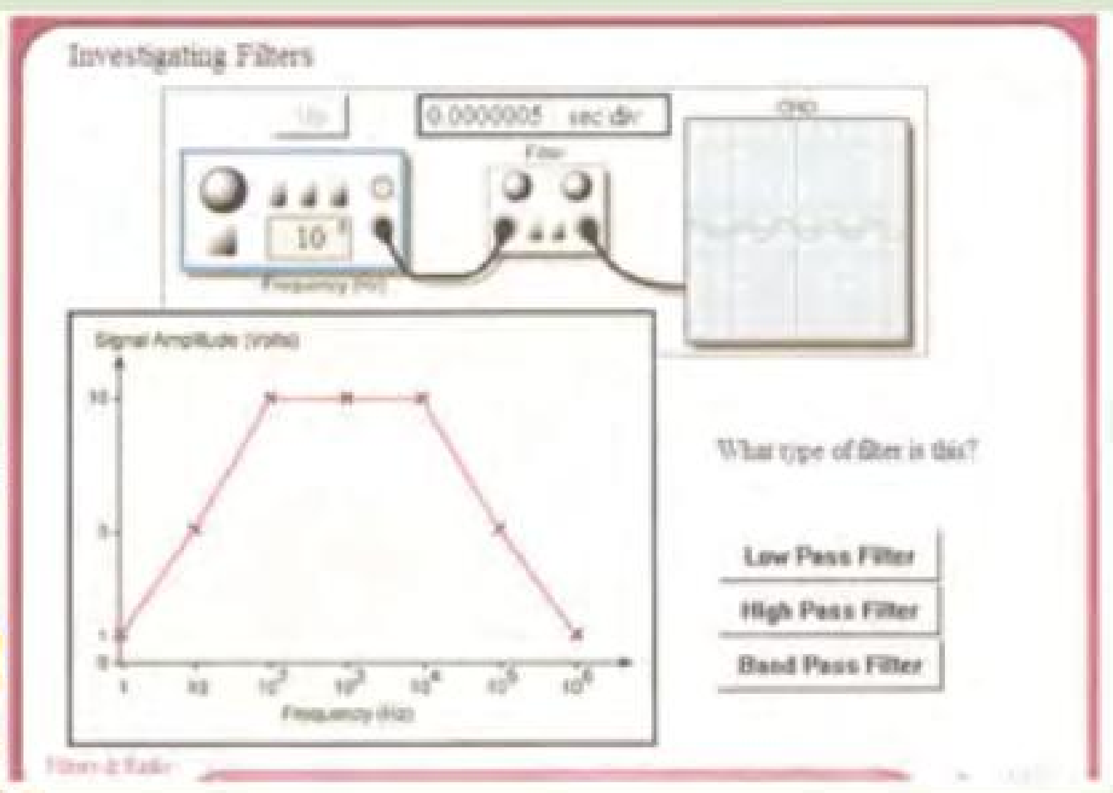

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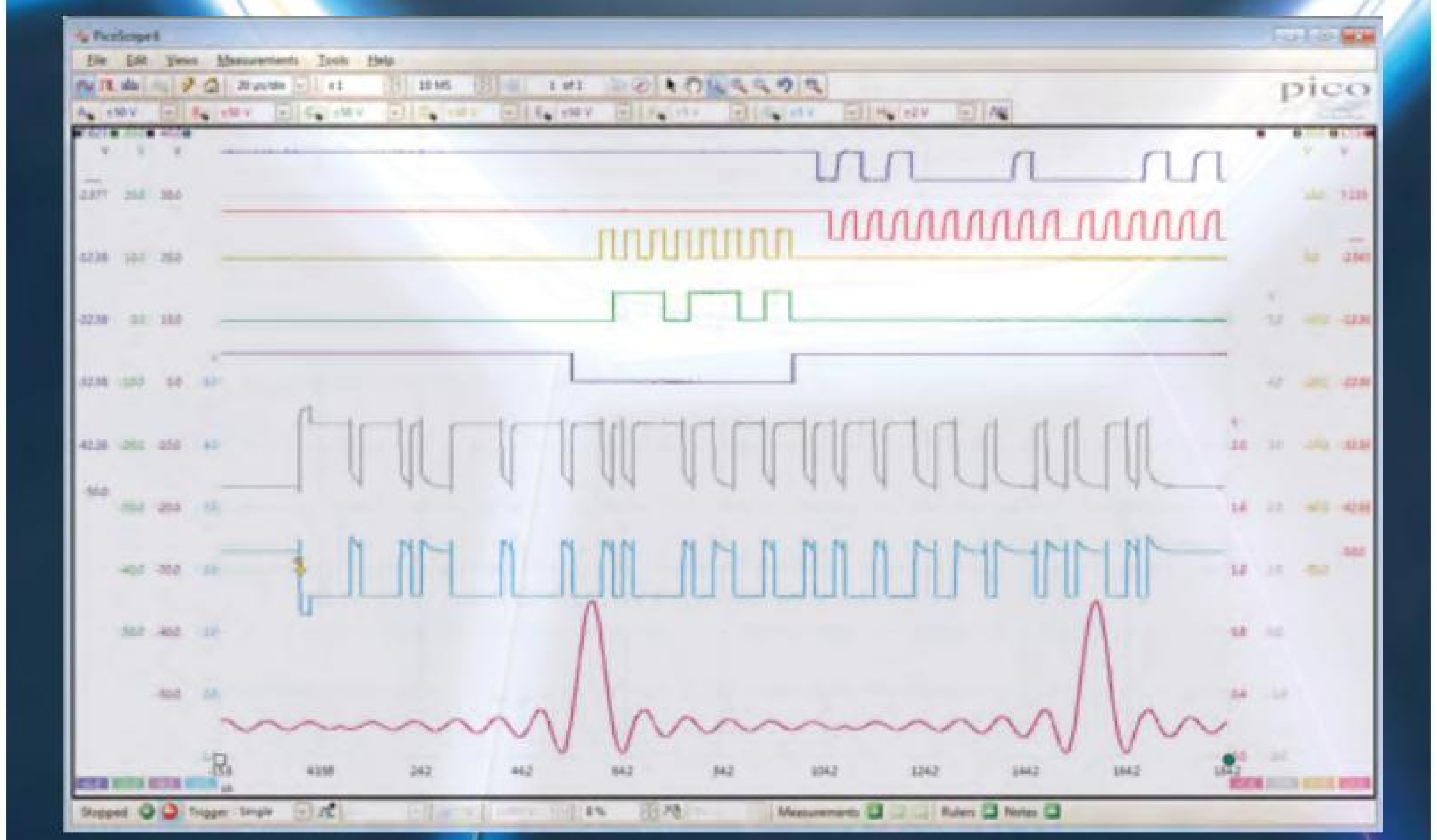

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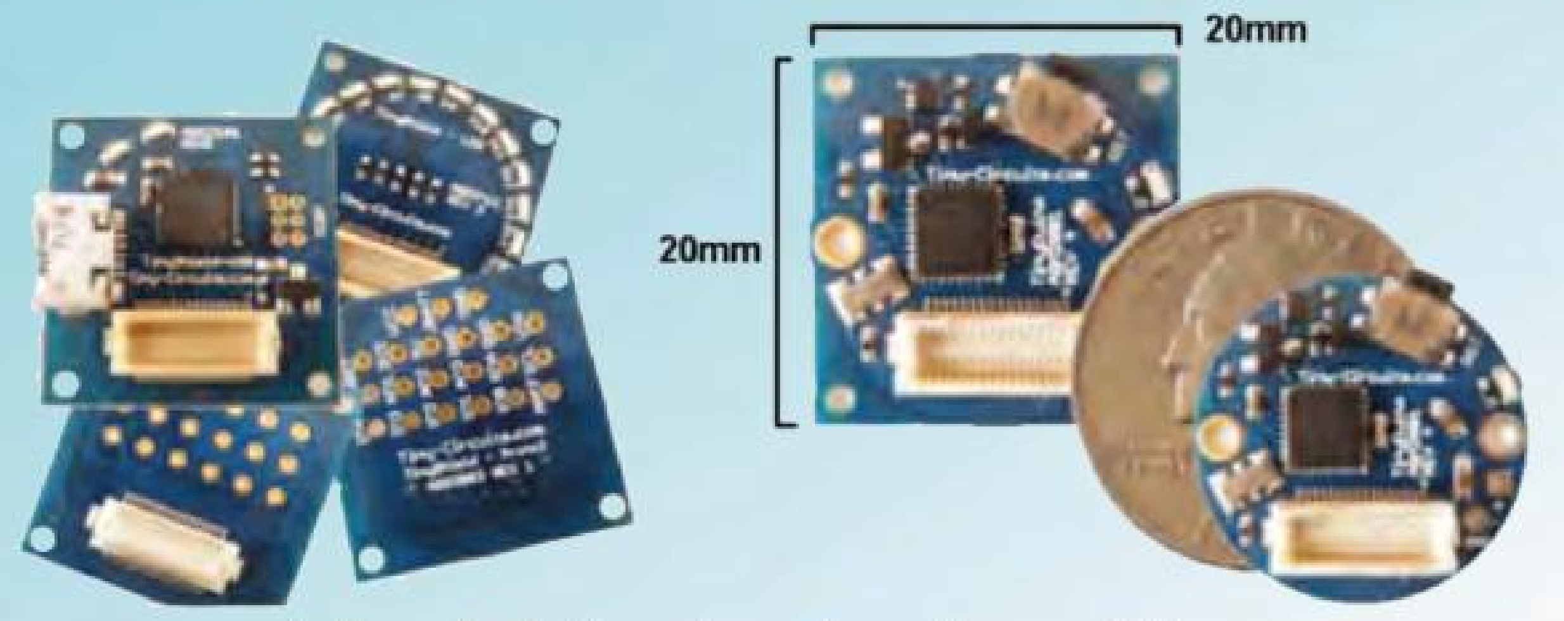

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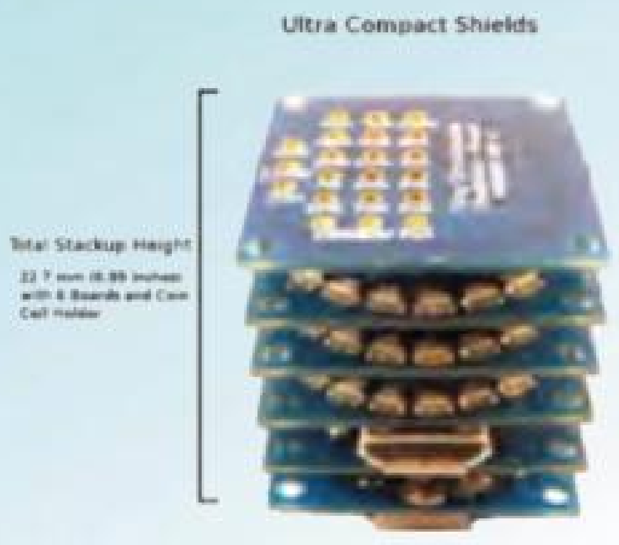

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NET WORK

by Alan Winstanley

Cloud formations

WELCOME to this month's *Net Work*, the *EPE* column specially written for Internet users. Just as networking has now become an everyday feature in modern homes, the 'cloud' has fast become an accepted medium for hosting external data or services. Rather than struggle with home computers, hard disks, operating systems and viruses, simply reach out over the web and access your documents or apps on the cloud instead – in theory anyway. All that most users need to know is that the cloud is 'out there' somewhere, and that keeping it in shape is someone else's problem. An increasing number of IP-connected appliances, such as those in the Samsung Smart Home or the Philips Hue Wi-Fi LED bulbs mentioned in May's issue, all connect to their corresponding manufacturer's cloud as well.

Acer C720 is a modern Chromebook and requires Wi-Fi access

Another sign of how cloud-based systems are gradually gaining a foothold is the so-called 'Chromebook' laptop, which uses Google's Chrome operating system to connect to the web, where word-processing, spreadsheets, PDFs, Google Drive, video and more can be accessed. For example, the Acer C720 Chromebook has a chiclet-style keyboard, 11.6-inch TFT screen and 16GB solid-state drive. Some versions also have a touch screen. Wireless 802.11n and USB3.0 are included, but there are no optical drives or Ethernet ports, which makes users entirely reliant on wireless access to use their machine. Apps for Chromebooks can be downloaded in the web browser by visiting the Chrome Web Store and a wide range of productivity, entertainment, lifestyle and business apps is available: see **https://chrome.google.com/webstore/category/apps** for a selection. Apart from needing Wi-Fi access to do any useful work, a Chromebook has many attractions, including almost instant-on start-up times, low weight and decent battery life. They cost typically £200 or so and are worth considering if you would like tablet-style usage coupled with a proper keyboard.

Non-Chromebook users need not feel left out; while visiting the Chrome Web Store, you might notice a range of 'extensions' that are also available. These plug-ins are designed to add onto a *desktop* installation of Google Chrome in the same way that plug-ins can be added to Firefox. All manner of blogging, productivity, shopping, ad-blocker extensions and lots more can be downloaded via your PC's Chrome browser. You can also personalise your Chrome desktop browser by skinning it with a theme fetched from the Chrome Web Store. Don't forget to keep your Chrome browser up to date, and this can be checked via the browser's About menu item. Beyond a Chromebook, there are many well-specified Windows laptops available, which offer users plenty of productivity. 'Power users' will still opt for a desktop computer – maybe backing up their data on the cloud.

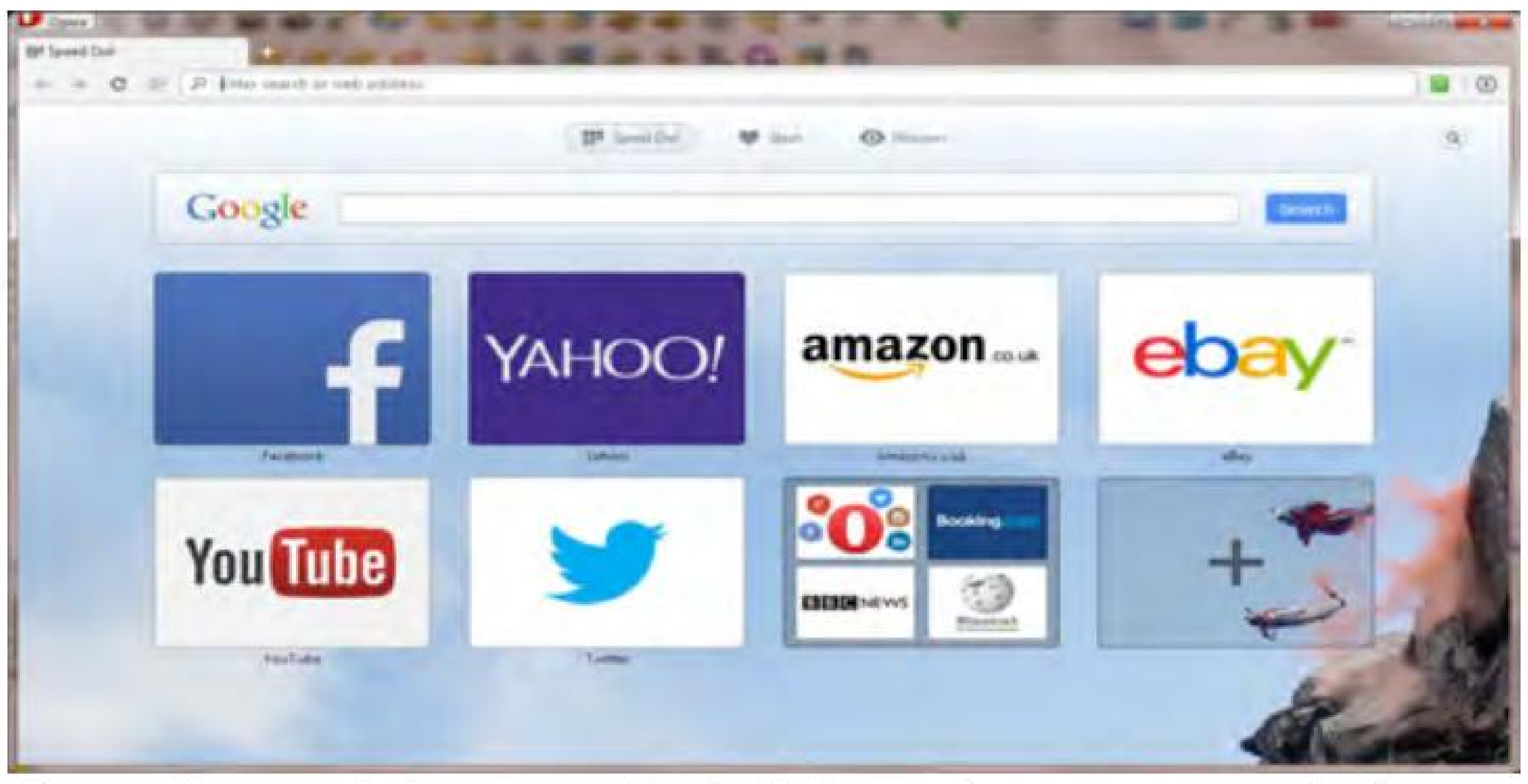
It's possible that only a committed Google fan will dabble much with the Chromebook way of doing things, but having a Google account is fast becoming a compulsory part of our digital lifestyle. Google users take for granted the fact that their Gmail and web traffic will be 'read' by Google in order to place topical advertisements, and favourite YouTube movies are also monetised by Google, who splice adverts into the most popular ones. Microsoft, on the other hand, offers their **outlook.com** email service as an alternative to Gmail, and they even claimed in a marketing campaign that Gmail raises privacy issues because Gmail traffic is analysed in search of advertising opportunities. Microsoft's position on Gmail privacy was recently upheld in a ruling by the UK Advertising Standards Authority. Microsoft merely scans traffic for viruses like any other ISP would, but does not use this for advertising purposes.

Microsoft has previously tried to boost its privacy credentials by promoting the 'Do Not Track' (DNT) feature first found in Internet Explorer 10 (see *Net Work*, July 2013). DNT was an industry effort to offer web users some relief from the creepy feeling that one's web surfing habits were being used to target them with advertisements. At the time, Microsoft went as far as advertising on TV the fact that its IE10 browser implemented Do Not Track. Since then, there has been much in-fighting in the working group responsible for DNT, as Internet advertising groups clash with privacy lobbyists. With all factions seemingly at loggerheads, the progress of the DNT initiative has all but ground to a halt, which means that mainstream websites may not comply with a user's DNT preferences anyway. At the time of writing, the Do Not Track test page at: **http://ie.microsoft.com/testdrive/browser/donottrack/** still runs, so you can learn how to enable Do Not Track in your preferred browser, but DNT appears to be broken and is far from being the panacea to our online privacy concerns.

Windows XP hangs on

By the time you read this, official support for Microsoft Windows XP will have been withdrawn. This means no more downloadable patches or security fixes for the venerable (vulnerable?) OS or its web browser, but Microsoft's support for its anti-malware tool will continue until 2015. Microsoft has done a decent job of supporting this ancient OS, and there is plenty of XP-compatible software still around. For now, I can see no reason to throw away a perfectly good XP machine, provided that good anti-virus software is maintained (eg, Kaspersky, Avast or AVG) and that dodgy-looking websites and emails are avoided. The newest versions of software don't always marry well with old hardware though, even if they claim to be XP compatible, so don't expect sprightly performance from an elderly single-core processor. Ideally, use a more modern browser rather than Internet Explorer (which is permanently stuck at IE8 on Windows XP) – current web browsers promise to be kept up to date for the foreseeable future.

On an older PC, Internet Explorer can handicap a user's web surfing, and more browser incompatibilities with key websites are becoming apparent. Tired of waiting for Internet Explorer to churn over and respond, and slowed down even more by those pesky streaming advertisements, I find myself adopting Firefox for all routine surfing, especially where features such as photo-uploading are needed. The often-overlooked Opera browser for PC, Mac, Linux, mobile phones and tablets is also worth trying, especially on slower, older machines; see: **www.opera.com**.



Opera is a web browser that's light and easy to use. Its 'speed dial' panes are one-click shortcuts to favourite sites

An upgrade to Windows 7 or 8 is another option for XP users, and a software tool can be downloaded from **microsoft.com** to check whether Windows 8.1 will run on legacy hardware. When upgrading the OS, my personal preference is to use a new hard disk and keep the old one for reference just in case. Microsoft is also offering free software to help port user data to a new system, along with a free copy of Laplink to transfer user data onto a new PC. See **windowsxp.com** for details.

NAS update

If cloud storage is still a dream due to the cost or the lack of local bandwidth, then the next best thing is to add some disk storage onto the home network instead. Regular readers will know that I use a Synology Network Attached Storage (NAS) unit on my own LAN. This disk unit connects to the router and can be accessed by PCs or laptops on the network, as well as by DLNA-compatible devices such as a Smart TV. After several years of constant use, the Synology has proved a dependable and satisfying piece of hardware that is used to store data and media files over the network. The device can also act as a hub for IP-based surveillance cameras; a small number of useful apps are also provided by Synology that are compatible with some external services. In my Windows clients I assign drive letters M:, P: and V: for music, photos and video files that are hosted on the NAS.

The Synology DS211J NAS has its own Linux-based web operating system (Synology DiskStation Manager or DSM) that is blessed with a faultless updating process. The NAS has two disks operating in a RAID-like mode. While this does not prevent data files from being overwritten with garbage, in the event of disk failure the data on the other disk should still be secure and the RAID setup will thus have done its job in protecting your data.

Hardware upgrades

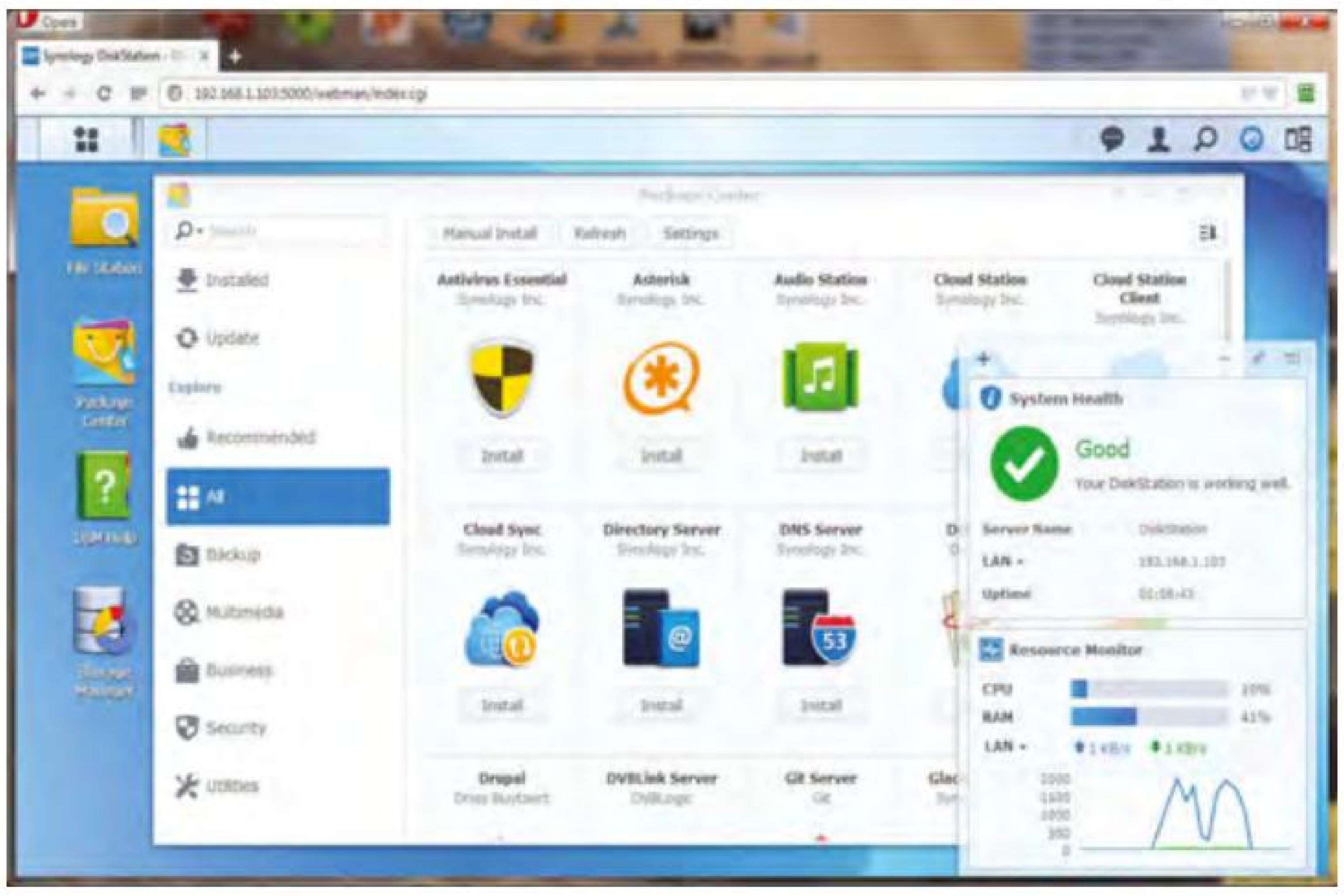
This brings me back to the subject of hardware upgrades. I noticed that one of the NAS unit's Samsung hard disks was starting to 'stutter' when booting up; its head hunting around erratically, the potential sign of a major disk problem. The NAS software provides a hardware check of each disk's SMART (Self-Monitoring, Analysis and Reporting Technology) status, and sure enough, one disk generated a large number of errors and it repeatedly failed the SMART tests that I ran manually from within DSM.

When a disk failure is looking likely, the first course of action is to leave the disk running and not power it down, in case it doesn't boot up again. It's best to back up any existing data, which in my case was done using a 1TB pocket drive hooked to the Synology's USB port. It's necessary to log into the NAS and use the system's own file manager for this – and then copy all the data folders over to the attached pocket drive, a process that takes many hours, but can be left running in the background.

Separately, the search was on for some replacements to upgrade the two-and-a-half-year-old Samsung 750GB Spinpoints. The hard disk market has been consolidating for several years, after HDD prices trebled when floods in Thailand seriously damaged manufacturing capacity (as discussed in *Net Work*, March 2012). I was attracted to Western Digital's 'Red' range, which they claim is optimised for NAS and enterprise use. Synology states that these disks have been stress-tested and are compatible with the NAS in question, so an order was placed with Scan (**www.scan.co.uk**) and a pair of WD10EFRX 1TB disks arrived the next morning.

The disk changeover was simple enough. Then the tedious job of restoring backup data was eventually completed, a very slow process that was hampered by a puzzling configuration problem or two. The network shares were frustrating to set up, but eventually Macrium backup software was writing scheduled backups onto the NAS once again. Installing the Media Server app prepared the Synology for Smart TV use.

As my failing Samsung disks perhaps proved, you can't put any old hard disk into a RAID system. The Western Digital disks are exceptionally quiet, so much so that the NAS is only a metre away in the corner and does not disturb me at all. As the drives run much cooler, another bonus is that the NAS fan is almost never heard and it runs in 'Quiet' mode, reducing noise very considerably. The disks also have a three-year limited warranty (register online). It's possible to buy even larger NAS units holding four disks or more, and Western Digital Red drives are claimed to run in up to five-bay installations – one major factor is the need to minimise disk vibration which may affect neighbouring disks.



Synology's latest version of DiskStation Manager (DSM) is used to manage the server

An upgrade to the Synology DSM was performed very smoothly, and the interface now sports the popular flat tile design. The Synology is configured to turn on automatically in the morning and after three months of faultless use the disk upgrade has been a total success, ensuring that the Synology remains one of my favourite pieces of hardware.

For those who have a bottomless budget, it's worth highlighting the Synology DS214play, a twin-bay NAS server that also offers built-in lossless multimedia transcoding. This provides on-demand HD video streaming across the network without needing to worry about having compatible codecs installed on the network client.

That's all for this month's *Net Work*. You can contact the author at **alan@epemag.demon.co.uk.**

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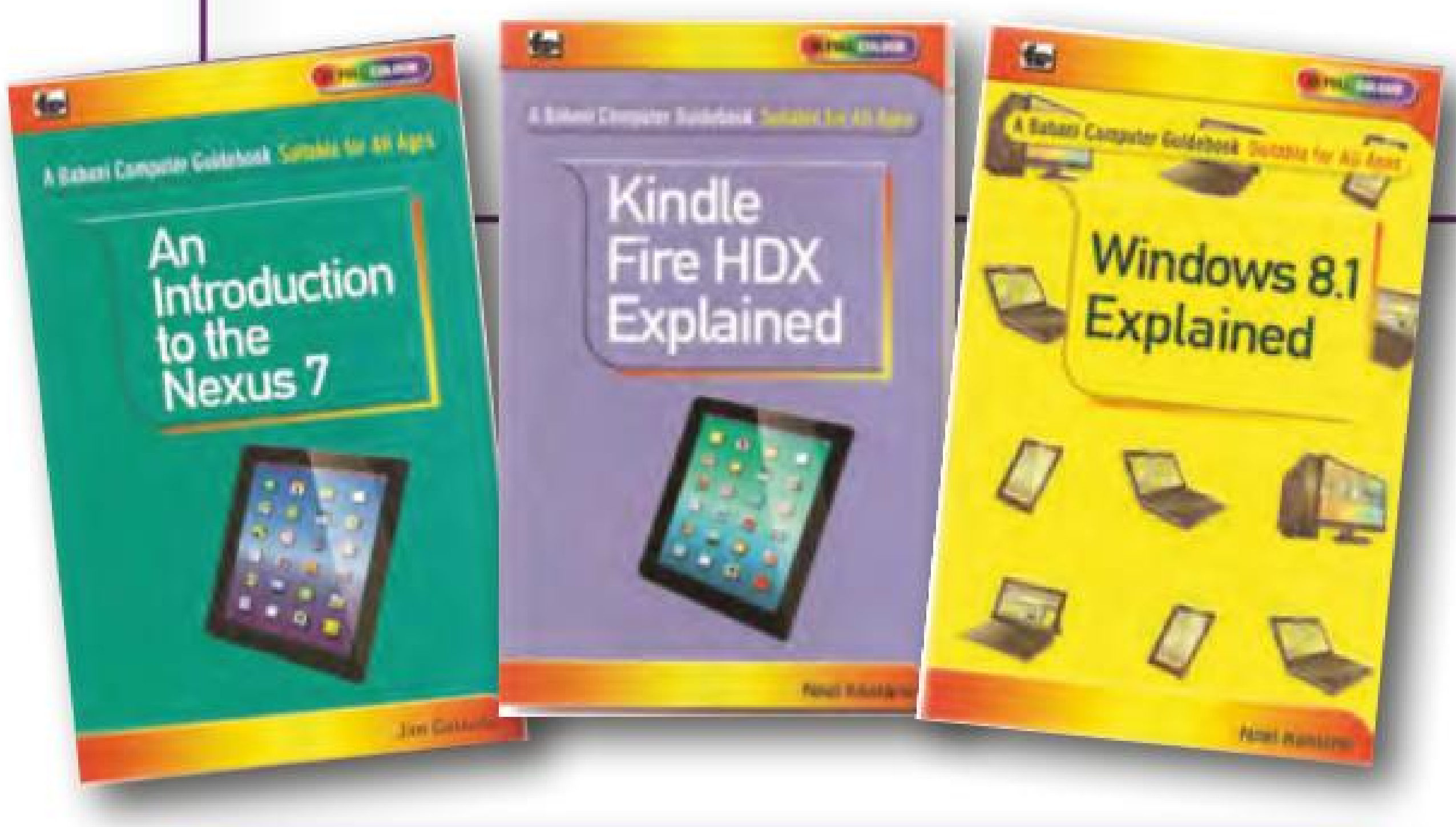

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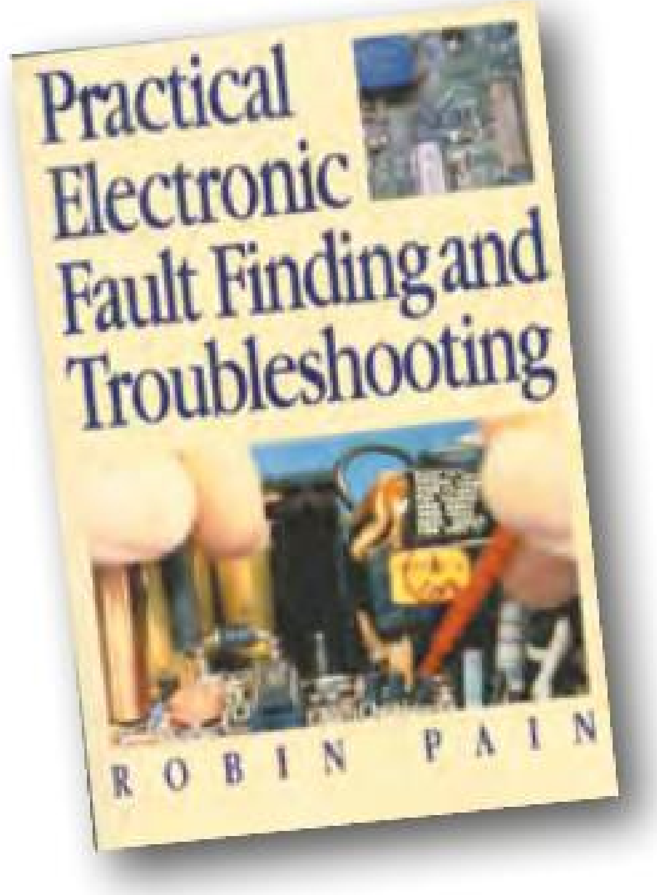

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Basic printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are drilled and roller tinned, but all holes are a standard size. They are not silk-screened, nor do they have solder resist. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. * **NOTE: PCBs from the July 2013 issue with eight digit codes** have silk screen overlays and, where applicable, are double-sided, plated through-hole, with solder masks, they are similar to the photos in the relevent project articles.

All prices include VAT and postage and packing. Add £2 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

PROJECT TITLE	ORDER CODE	COST
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Jump Start – Egg Timer	896	£8.36
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MAY '13		
Electronic Stethoscope	898	£9.72
PIC/AVR Programming Adaptor Board (d'ble-sided)	899	£23.33
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JUNE '13		
USB Breakout Box	901	£7.97
Jump Start – Simple Radio Receiver	902	£8.94
Mix-It	903	£11.28
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MAY '14		
The CLASSiC-D ±35V DC-DC Converter	11104131	£16.66
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Teach-In 2014 – Part 9 Pi Camera Light	905	£13.44

*** See NOTE above left regarding PCBs with eight digit codes ***

Please check price and availability in the latest issue.
A large number of older boards are listed on, and can be ordered from, our website.
Boards can only be supplied on a payment with order basis.

EPE SOFTWARE

★ All software programs for *EPE* Projects marked with a star, and others previously published can be downloaded free from the Library on our website, accessible via our home page at: **www.epemag.com**

PCB MASTERS

PCB masters for boards published from the March '06 issue onwards can also be downloaded from our website (**www.epemag.com**); **go to the 'Library' section.**

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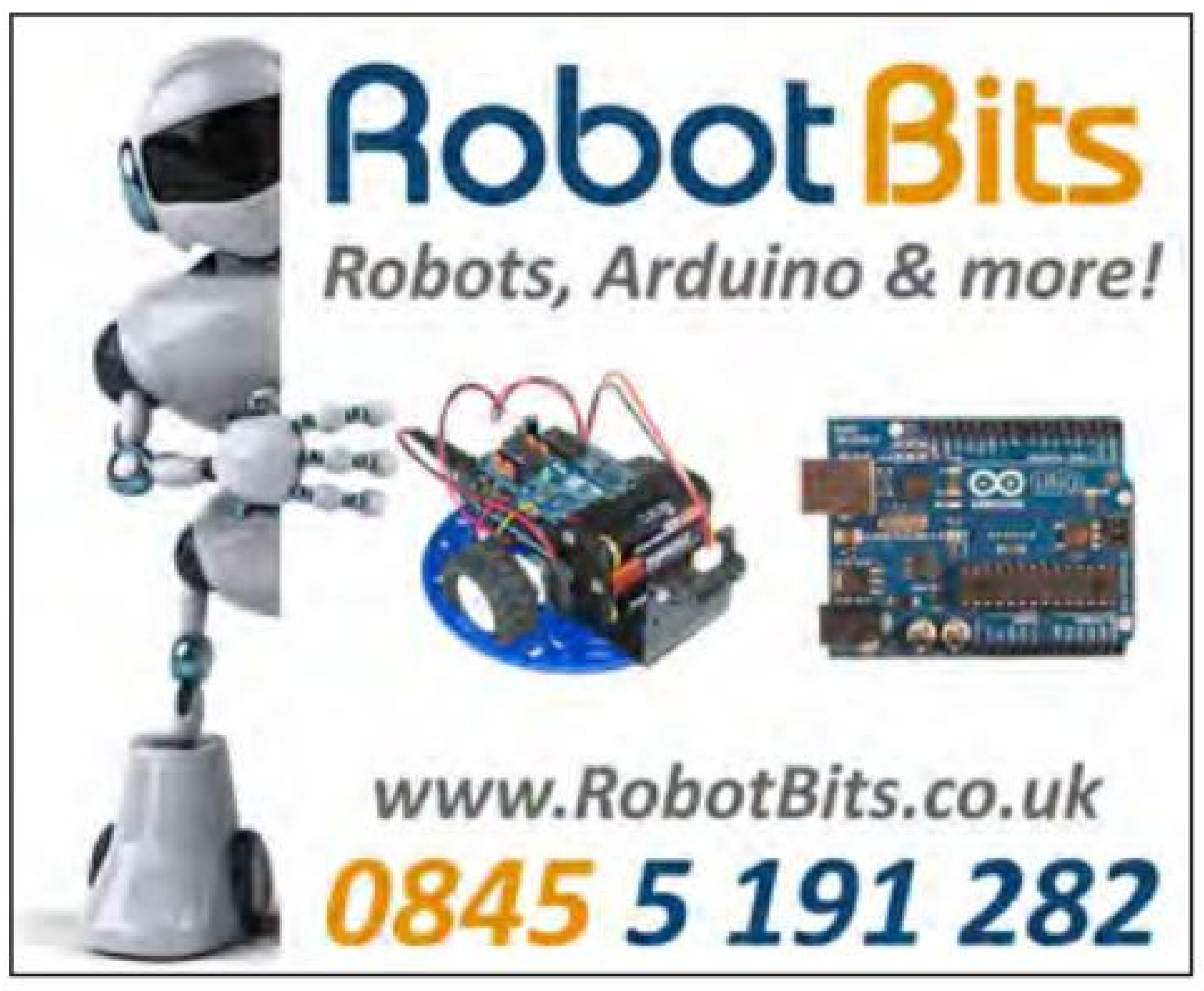
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Next Month

JULY '14 ISSUE ON SALE 5 JUNE 2014

Content may be subject to change

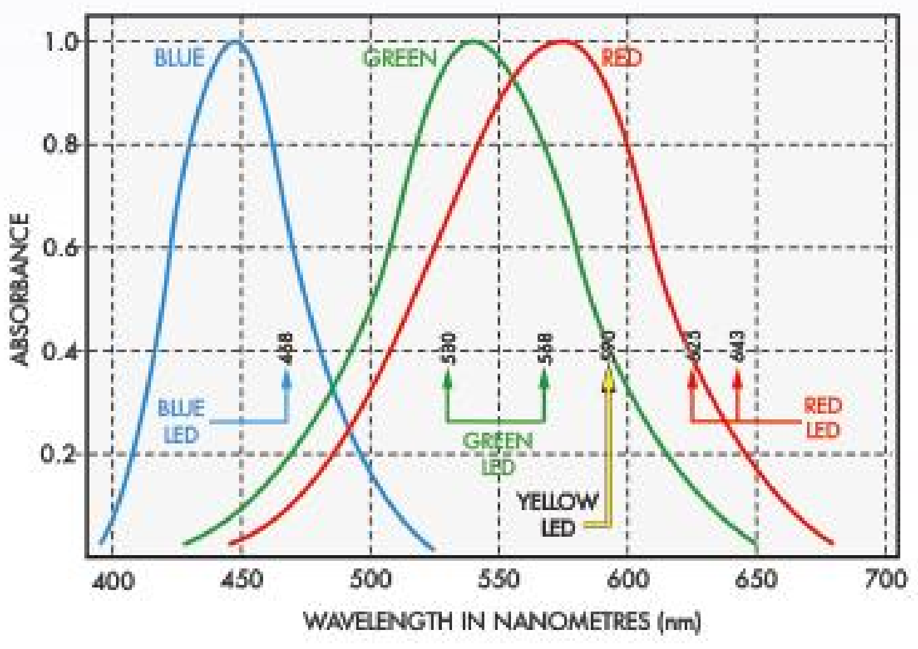
10-Channel
Remote Control
Receiver
Channels

Versatile 10-Channel Remote Control Receiver

This 10-channel control system can be used with any universal IR remote control. It can also be controlled via a UHF link, so you don't have to worry about range or high light levels affecting infrared operation. It can switch relays (and other devices) on and off, making it ideal for controlling motors, lights, solenoids, door catches or even robots!

Two demonstration circuits for human colour vision

The human eye can see a range of different colours, from deep red down to deep violet. But we can be fooled into seeing many colours by a TV screen that contains just red, green and blue light emitters (RGB). Why is that? And why do printers use a different set of colours: cyan, magenta, yellow and black (CMYK)? These two simple circuits aim to reveal the operation of the human eye and clear up the mysteries through practical demonstrations.



Li'l Pulser Model Train Controller

This outstanding train controller comes with a host of features and delivers up to 8A of output current. Highlights include: pulse power for smooth running, excellent low speed control, inertia and braking simulation, track voltage LED indication, over-current/short circuit alarm and much else!

Teach-In 2014: Raspberry Pi – Part 10

Next month, in the final part of Teach-In 2014, our Pi Project features the construction of a real-time clock interface for the Raspberry Pi. Python Quickstart will show you how tkinter can help you to improve the user interface by adding labels and buttons, and we will also have the answers to our Home Baking Quiz. Finally, we will also provide you with a comprehensive index to all ten parts of the series.

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Raspberry Pi – are you kidding?

by Peter Brunning

When I first saw the name I could not image anyone calling a serious product by such a weird name. The next I new it was in the news for hitting one million sales. That did it, I had to have one to find out if it really is as brilliant as the their advertising would have me believe,

A few days later my first impression was amazement. It is an incredible collection of the very latest technology at an unbelievably low price. I have wanted a new monitor for some time so I purchased a modern high definition 21 inch. Being the latest LED type monitor it had not occurred to me that I would need an adaptor to connect it to the Raspberry Pi. So adaptor purchased and a beginners book and a short time later the system was working.

I have been writing programmes for many many years but never used the Lynx system, so I worked through some examples in the beginners book. No problem getting the right results but as I worked away my excitement faded. An hour of this and I had had enough.

The problem is highlighted by the names which are used to call the subroutines. These have a similar ring to them as Raspberry Pi, and are typical of names found in computer games. Young technical people's idea of fun. But who cares what they are called the system works beautifully, the question is - what are we learning by using this system?

At the heart of the Raspberry Pi is a powerful microcontroller and if we were learning to programme this chip it would be great. The problem is the complexity of the system stops us learning to use the chip. We are learning to use the system and we do this by using ready made subroutines. So the learning tends to be specific to the particular arrangement of the Raspberry Pi.

If you are working on a project where it is practical to build in a complete Raspberry Pi then you have a brilliant solution.

The Brunning Software P931 PIC Training Course

This is almost a completely opposite system to the Raspberry Pi. We learn to use a relatively simple bare microcontroller. We make our connections directly to the input and output pins of the chip and we have full control of the internal facilities of the chip. We work at the grass roots level.

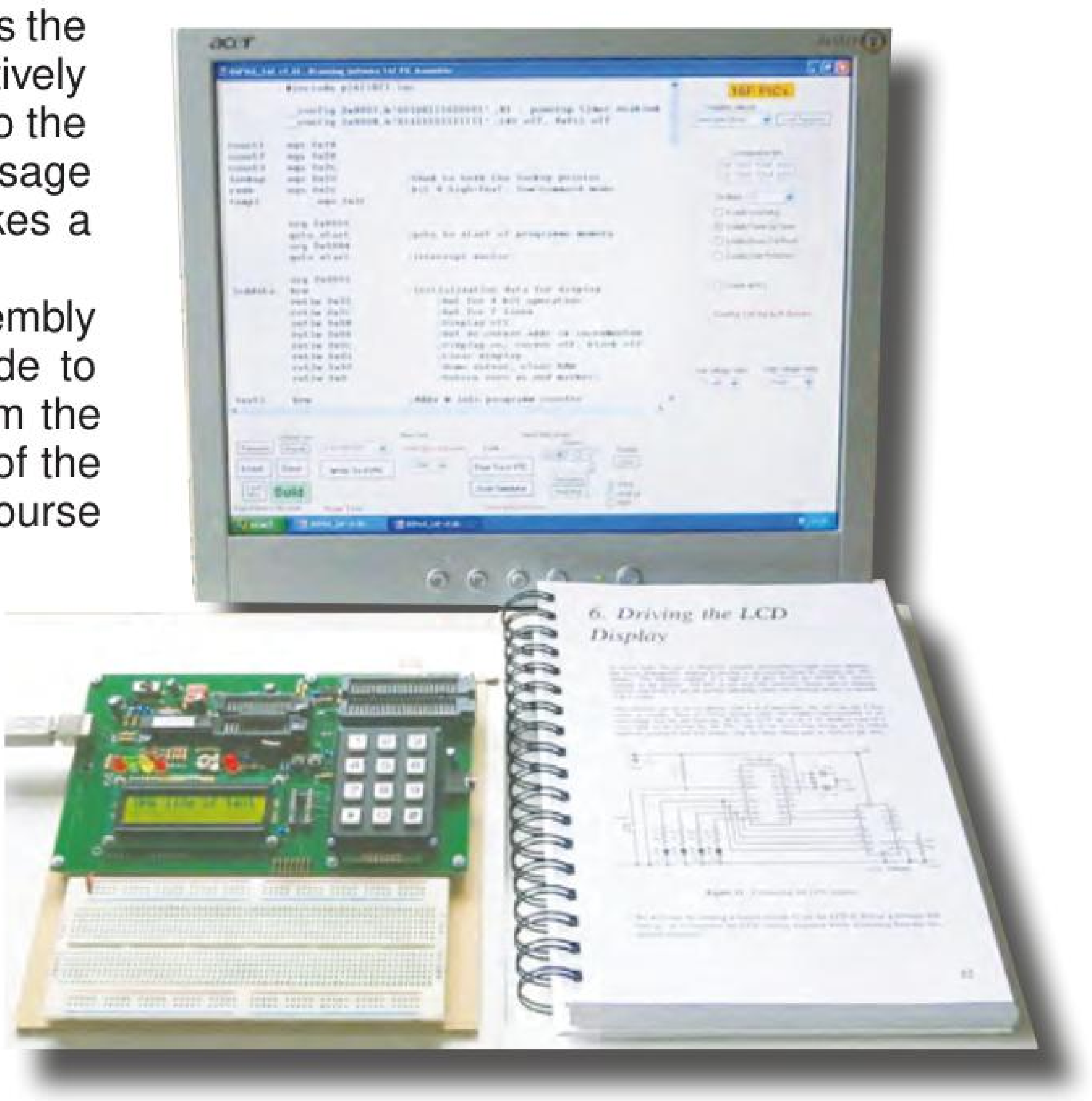
Lets imagine you have a project where you want to use a microcontroller within your hardware to optimise the operation, and you want some sort of external monitor of the current status. This is your own original project so there is no readily available software to programme into the microcontroller.

The first book of the P931 course includes using the microcontroller to drive an alphanumeric liquid display. So an LCD could easily be used to display progress messages. The optional third book of the course teaches programming of a PC and includes the use of our easy USB system. So after some more study it is relatively easy to add a serial link from the USB port of the microcontroller to the USB port of your PC, then use the PC to display the progress message and the PC mouse can be used to control the process. That takes a good deal of study but it is all relatively easy.

I have a preference for writing the control programmes in assembly language (first book of the course) but if for example you decide to wade into USB control using the extensive libraries available from the Microchip website you would first need to gain an understanding of the C programming language for PICs. The second book of the P931 course introduces PIC C for absolute beginners.

The operation of USB is particularly complicated so we created the Brunning Software Easy USB system which allows a simple assembly language "call" to send individual bytes to and from the PC.

The P931 course teaches how to create your own original software using PIC assembly language, PIC C, and PC visual C#. The third book Experimenting with Serial Communications (using visual C#) is an optional extra.



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